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DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GYPSUM DEPOSITS

IN THE

UNITED STATES

BY

GEORGE I. ADAMS AND OTHERS

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., November 18, 1903.

SIR: I have the honor to transmit herewith the manuscript of a report on the gypsum deposits of the United States, with the recommendation that it be published as a bulletin.

The report consists of a comprehensive summary of existing knowledge regarding the gypsum deposits of the United States, compiled by Mr. George I. Adams, with the collaboration of numerous other geologists, who have prepared chapters on the gypsum deposits of the several States. Through the assistance of these experts the report contains not only a summary of all published information on the subject, but much additional information not elsewhere available.

Very respectfully,

C. W. HAYES,
Geologist in Charge of Geology.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

GYPSUM DEPOSITS IN THE UNITED STATES.

INTRODUCTION.

By George I. Adams.

In this bulletin an attempt is made to set forth such information as is available concerning the gypsum deposits of the United States and their economic development. Much of the information may be found in technical and scientific journals, in the geologic and statistical reports of the States, and in the publications of the United States Geological Survey. Some of these publications, however, are now out of print. The individual chapters relating to the deposits in the various States have been prepared by members of the United States Geological Survey, who have studied them incidentally while engaged in broader or allied problems, or by other scientists who have devoted considerable time and energy to the subject. The gypsum deposits of the country have never been made a subject of exhaustive inquiry. It has not been possible to do special field work, except in certain localities, and hence the descriptions of deposits are not uniform. Another reason for the variation in the chapters relating to the individual States is found in the diverse conditions of development in the different regions, since the progress in exploration and the study of the conditions of occurrence can not go much in advance of the commercial demand.

Many interesting details have been omitted, since the bulletin covers a wide scope and must necessarily be concise. It has been deemed advisable to specially emphasize the economic conditions, and accordingly the geologic relations of the deposits and theoretical questions are not extensively treated. The writer discusses briefly the technology of gypsum, and considers in a general way the questions pertaining to its occurrence and utilization. The statements concerning the economic development are based on information which he has obtained in collecting statistics for the division of mining and mineral resources of the United States Geological Survey.

GEOLOGY, TECHNOLOGY, AND STATISTICS OF GYPSUM.

By GEORGE I. ADAMS.

PROPERTIES OF GYPSUM AND THEORY OF FORMATION.

CHARACTER OF GYPSUM.

Gypsum is a hydrous calcium sulphate. Its chemical composition is expressed by the formula $CaSO_4.2H_2O$, which may be interpreted as calcium united with sulphuric acid and holding water of crystallization. The percentage of these materials by weight is calcium 32.5, sulphuric acid 46.6, water 20.9. The mineral is not infrequently impure, as the result of other substances present during its formation or deposited subsequently in intimate relation with it. These impurities are usually organic matter, iron compounds, clayey material, and the carbonates of lime and magnesia.

The color of gypsum when reduced to powder is white. In its natural form, when pure, it is usually white when massive, and pearly or glistening when crystallized, the crystalline form being transparent, sometimes to a remarkable degree. Gypsum is often gray, flesh-red, honey-yellow, ocher-yellow, or blue. As the result of impurities it may be brown, red, or reddish brown, and sometimes black.

The hardness of gypsum varies from 1.5 to 2.0, the crystalline form being taken as the standard for the second degree in the scale of hardness of minerals. It can be scratched with the finger nail, which is the common test applied to distinguish it from other minerals that have a similar appearance.

The specific gravity of gypsum, i. e., its weight as compared with pure water, is 2.3. At a temperature of 26° C., which is practically the ordinary temperature, one part of gypsum is soluble in 372 parts of water. As a matter of comparison it may be stated that at the same temperature 40 parts of common salt will dissolve in 100 parts of water. The presence of other salts in solution, as common salt, and especially potassium salts, increases the amount of gypsum which may be dissolved. When heated sufficiently gypsum gives off its water of crystallization and becomes opaque, being altered to anhydrite. It does not dissolve in sulphuric acid, and when acted on by other acids does not effervesce or gelatinize. It fuses, coloring the flame reddish yellow. When ignited at a temperature not exceeding 260° C. it will again combine with water and set.

VARIETIES OF GYPSUM.

Crystallized gypsum, or selenite, as it is called, when pure is colorless and transparent. It occurs in distinct crystals or broad and often large folia or sheets. Typical forms of gypsum crystals are shown in Pl. I, *B*, and fig. 1. The cleavage of gypsum parallel to its principal plane is perfect. (See Pl. II, *B*.) Along the cleavage planes gypsum separates into thin plates, which are flexible to a limited degree but not elastic. This characteristic serves to distinguish gypsum from mica, with which it is sometimes confused under the improper name of isinglass. Selenite and its massive form gypsum may be readily distinguished from calcite and its massive form limestone by the difference in hardness, since calcite and limestone can not be scratched with the finger nail.

Fibrous gypsum (see Pl. II, *A*), or satin spar, is a crystalline variety, having a pearly appearance.

Massive or rock gypsum (see Pl. IV), in which the crystals are minute, even microscopic, is usually white. It not infrequently occurs in thick

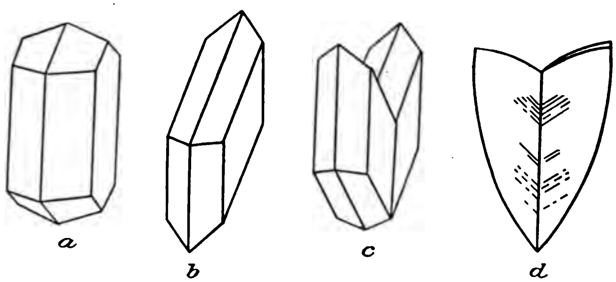


FIG. 1.—Forms of gypsum crystals. *a*, *b*, common; *c*, *d*, twinned.

strata interbedded with limestones and shales. Rock gypsum may contain, as impurities, clay, carbonate of lime, and silica, and so be variable in color. When fine grained and suitable for carving and sculpturing, it is known as alabaster. This variety is slightly translucent.

Earthy gypsum, or gypsite, as it is sometimes called, is not compact. It may be granular like sugar, or may occur in beds having an earthy texture. Such beds are usually near the surface, and are often very impure.

Gypsum sand occurs in some regions where rock gypsum is abundant, and is formed by wind erosion. It accumulates in dunes, in which it is mixed with fragmental material from other rocks.

Many natural waters contain gypsum in solution, having derived it from the rocks and soil through which they have passed. Pl. V, *B*, represents a mass of rock gypsum that shows the effects of solution. Such waters are called permanently hard; that is, they will not soften when boiled in the ordinary manner, or, more accurately, they retain the gypsum in solution after being boiled. The solubility of gypsum

in water decreases after a certain temperature is reached, owing to the formation of anhydrite. To this fact is due the formation of boiler scale when gypsum is present in water used for boiler supply. Water which is hard because it contains lime or calcium carbonate is rendered soft when boiled, through the precipitation of the lime as the result of the loss of the carbon dioxide which holds it in solution. Gypsum water is commonly stated to be undrinkable. As a matter of fact, gypsum has very little effect on the human system. The ill effects commonly attributed to gypsum water are due to the magnesium sulphate which it contains, this chemical being a common constituent of gypsiferous rocks. Gypsum is precipitated from water over the surface of the soil, and in this process other salts are commonly produced. The injurious results due to the efflorescence or white incrustation on soils where large quantities of water evaporate should be attributed to other minerals than gypsum.

ANHYDRITE.

Anhydrite has the same chemical composition as gypsum, with the exception that it contains no water of crystallization. By the absorption of moisture it changes to gypsum. This process occurs in nature, and results in the alteration of beds of anhydrite to beds of gypsum. Anhydrite may be distinguished from gypsum by its crystalline cleavage, which is in three rectangular directions, giving it a pseudocubic aspect. It sometimes occurs in formations which contain gypsum, and not infrequently is associated with beds of rock salt.

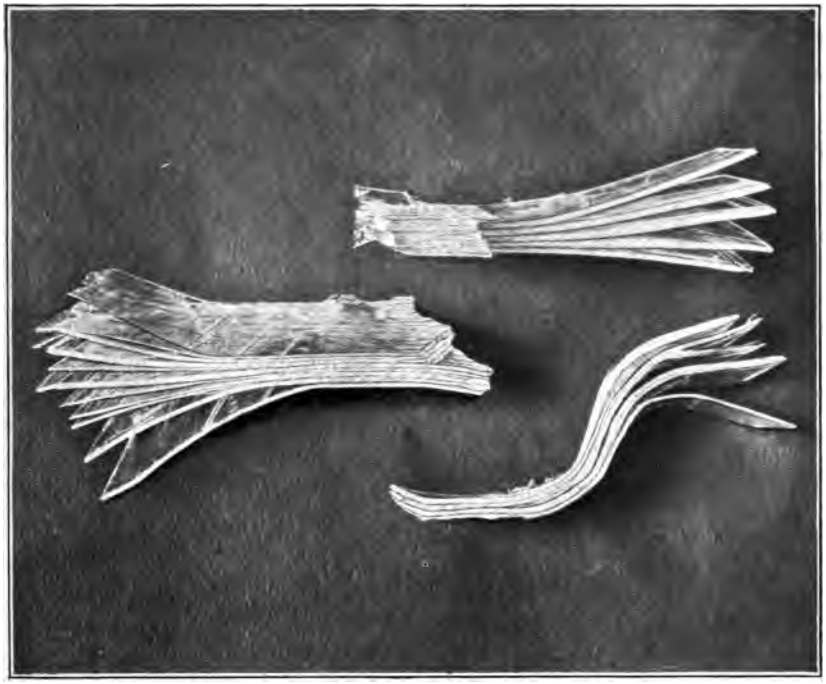
Anhydrite may be formed from gypsum solutions at various temperatures when the solutions contain certain other salts in sufficient quantities. For example, it has been found that in the presence of a saturated solution of common salt this change takes place at 30° C., which is a temperature reached in a summer day. This fact satisfactorily accounts for the formation of anhydrite in nature from concentrated sea water or lake brines.

Anhydrite in gypsum deposits affects the calcined product much the same as the addition of so much dead-burned gypsum would.

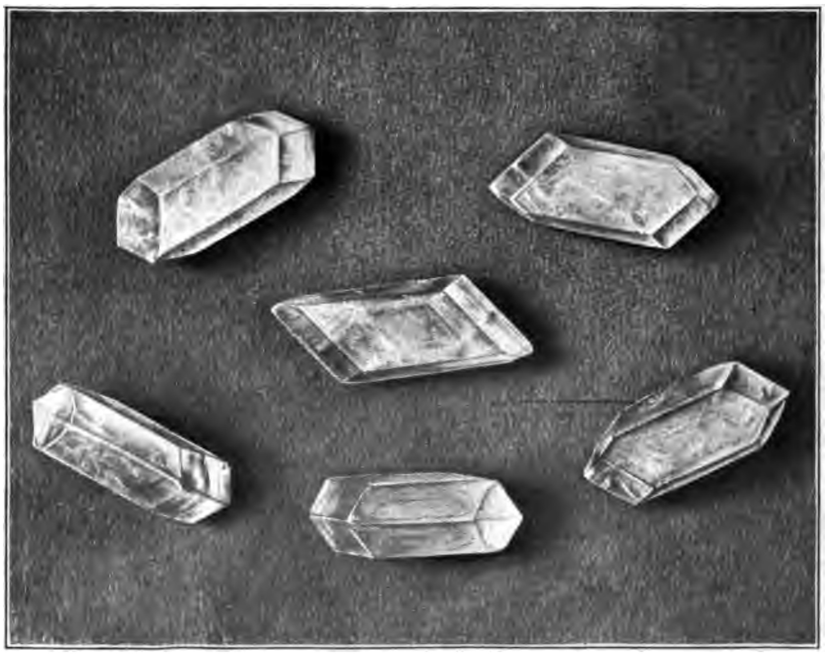
ASSOCIATED MINERALS.

In regions where gypsum deposits occur beds of rock salt are not infrequently found interstratified with the gypsum-bearing series. The association of gypsum and rock salt is due to the fact that they have had a similar origin, the general opinion in regard to them being that both have been formed by the concentration of sea water.

Sulphur deposits are occasionally found in intimate relation with the gypsum beds, and sometimes there is evidence that limestones have been in part altered to gypsum through the action of sulphate solutions. In certain fields where petroleum occurs the association of sulphur and gypsum, and occasionally of rock salt, has been noted. These



A. SELENITE WHICH HAS BEEN SPLIT AND BENT TO SHOW CLEAVAGE AND SLIGHT FLEXIBILITY.



B. SELENITE CRYSTALS.

cases are of much theoretical interest. The gypsum is accounted for by the reaction on limestone of the sulphate solutions derived from the oxidation of sulphides, such as pyrite. The reduction of gypsum through the agencies of decomposing organic matter, such as may have given rise to the petroleum, may have produced the sulphur.

FORMATION OF GYPSUM.

Gypsum may be formed in the laboratory by the chemical action of sulphuric acid on carbonate of lime. In nature this reaction may take place in a number of ways. Lime is quite universally distributed in the rocks.

Unimportant quantities of sulphuric acid form in nature by the oxidation of sulphurous acid and hydrogen sulphide. Sulphurous acid is known to escape from volcanoes and about fumaroles. The chief source of sulphuric acid, however, is the oxidation of certain sulphides, of which pyrite is the most abundant. Hydrogen sulphide, produced by decomposing organic matter or evolved by living organisms, is another source of sulphuric acid. Gypsum when formed may pass directly into solution or may form films and thin veins in the shales or other rocks which carry the pyrite. Sometimes free crystals are developed.

DEPOSITION OF GYPSUM.

The deposition of gypsum as a direct result of the processes which take place in its formation has given rise to only limited bodies occurring widely disseminated within the earth's crust. It is concentrated into economic deposits through water transporting it in solution. There are no chemical reactions necessarily incident to its precipitation from a solution. Although gypsum is not readily soluble in water, when once in solution it is held until evaporation causes it to be deposited. It is due to this fact that the circulatory ground water transfers it to the point of issuance of springs or into ponds and streams, from which it is carried into lakes and the ocean. When, through evaporation, these bodies of water are concentrated, the gypsum may be deposited. The processes of solution and redeposition may be repeated indefinitely.

ORIGIN OF ROCK GYPSUM.

The mode of origin of rock gypsum may be inferred from the fact that the beds are usually interstratified with shales, sandstones, and limestones which have been deposited in seas or lakes. The gypsum-bearing series are usually destitute of fossil remains, showing that the water had reached a degree of concentration which was unfavorable to life. Not infrequently the presence of iron oxide causes the associated rocks to have a red color. Such sediments are believed to have been derived from land areas which were deeply oxidized. The study of

the broader stratigraphic relations of the gypsum series usually shows that they were formed in local basins, and probably in landlocked arms or remnants of retreating seas. Beds of rock salt which are thought to have had a similar origin are sometimes found in the gypsum-bearing series; and this occurrence throws some light on the concentration of the sea brine which contained the various chemical salts in solution.

ORIGIN OF GYPSUM SEAMS AND VEINS.

Where jointing or fissuring has opened passageways for water through gypsum-bearing rocks, and where the water has circulated along the bedding planes, the gypsum which it holds in solution often crystallizes in seams and veins, which may be clearly seen to be of later origin, since they not infrequently cut the beds of gypsum. Large masses of selenite which are remarkable for their transparency and specimens of satin spar which have beautiful fibrous, pearly luster, are commonly formed in this way. The force of crystallization is not well understood, but it is apparent that in many instances it is powerful enough to lift rock masses and widen fissures. Where initial deposition of gypsum has taken place the crystal growth of the mass in the fissure may continue, and eventually result, by further widening of the fissure and increased growth of the mass, in the formation of large bodies. Just how much importance should be given to this method of deposition can not be stated, since it is a subject which has received but little attention.

ORIGIN OF GYPSITE, OR GYPSUM EARTH.

Gypsite, or gypsum earth, is usually found in regions where beds of rock gypsum occur, and it is probable that they have been derived from these primary deposits through the circulation of ground water. The spring theory of origin has been advanced by Mr. G. P. Grimsley, who has studied the deposits in Kansas, which were the first of this class to be utilized. The gypsite is found upon microscopic examination to consist of small, angular, gypsum crystals, some of which are perfect, but most of them have their terminations rounded by solution. This shows that they are not transported crystals, but are found in place. Mingled with them there are small quartz crystals and a considerable amount of poorly crystallized calcite, besides traces of organic matter. The position of the deposits with respect to the beds of rock gypsum and the location of them in low ground are favorable to the theory that they have resulted from the evaporation of spring water or solutions issuing in swampy places. In working the gypsite deposits springs are encountered which are troublesome when the gypsite is being removed. The presence of recent fresh-water shells associated with the deposits shows that they are of late origin.

A. FIBROUS GYPSUM FROM A FISSURE IN CLAY.

B. SPECIMEN OF SELENITE AN INCH THICK, ILLUSTRATING TRANSPARENCY AND INCIPIENT CLEAVAGE.

ORIGIN OF GYPSUM SANDS.

Many of the gypsum deposits in the western part of the United States are in relatively arid regions, where wind erosion is active. The disintegrating gypsum is carried by the wind with other detrital material and mingled with the surface deposits. This process does not usually give rise to economic bodies, but in certain localities there are gypsum sands which are of exceptional purity and of considerable extent. The most noted occurrences are the gypsum dunes in Utah, which were described by Mr. G. K. Gilbert, and the area known as the white sands in southern New Mexico, which has been described by Prof. C. L. Herrick. These areas are fully discussed below. The dunes of gypsum in New Mexico cover, irregularly, about 350 square miles. The area is one in which the stream and surface waters are impregnated with various salts. Evaporation produces an efflorescence or crust which, when it disintegrates, is blown by the winds into dunes. The more soluble salts are dissolved by the falling rains, but the gypsum, which is relatively insoluble, accumulates, and has given rise to the so-called white sands. In this region gypsum deposits are interstratified with the bed-rock series. The origin of the sands is in some respects not unlike the origin of the gypsum earth described above, but differs in the mode of accumulation.

GEOLOGIC AGE OF GYPSUM DEPOSITS.

Gypsum deposits occur in the rocks of practically every geologic system. Of those which are of economic value, the oldest known in the United States are found in Silurian rocks, in the central part of New York, in northern Ohio, and in the Upper Peninsula of Michigan. The next younger are the deposits of the Mississippian, or Lower Carboniferous series in Virginia, in the Lower Peninsula of Michigan, and in Montana. By far the most extensive are those which were laid down during Permian time. They embrace the beds found in the Black Hills of South Dakota and of certain parts of the Rocky Mountains, and extensive deposits which occur in Iowa, Kansas, Oklahoma, Texas, and New Mexico. The geologic relations of some of the gypsum in the Western States is not definitely known. It is believed, however, that in the Rocky Mountain and Great Basin regions the gypsum is largely of Mesozoic age, some of it certainly belonging to the Jurassic. In Tertiary times deposits were formed in the western part of the United States, but because of the abundance and availability of the other deposits of gypsum in that region the Tertiary beds have not been developed, except in California.

The change of place of deposition with the progress of geologic time has been due to the shifting of the seas, as a result of the gradual

emergence and submergence of the continental mass. There does not appear to be much difference in the character of the gypsum formed during the various periods, excepting as the purity was influenced by local conditions of sedimentation.

TECHNOLOGY.

THEORY OF COOKING OR BURNING GYPSUM.

The composition of gypsum is $CaSO_4.2H_2O$. It is a hydrated sulphate of lime, consisting of one part of lime sulphate to two parts of water. Careful experimentation has shown that when gypsum is heated to a temperature of about 132° C., it loses three-fourths of its water, and another hydrate is formed, having the formula $(CaSO_4)_2.H_2O$. Accordingly, calcium sulphate may be considered as having two hydrated forms. The first, which occurs in nature, is the more stable one; the second, in which the amount of water is less, is converted into the first when water is added to it. This hydrate is essentially plaster of Paris.

If gypsum is heated to a temperature of 343° C., all the water is driven off, and it is converted into anhydrite, which has the composition $CaSO_4$. This mineral exists in nature, and has a different crystalline form from gypsum. It is converted into gypsum on taking up water and recrystallizing. When it is produced artificially, it is a pulverulent mass, and is called dead-burnt plaster. If gypsum is heated to a sufficiently high temperature it fuses or melts, and on cooling is glassy.

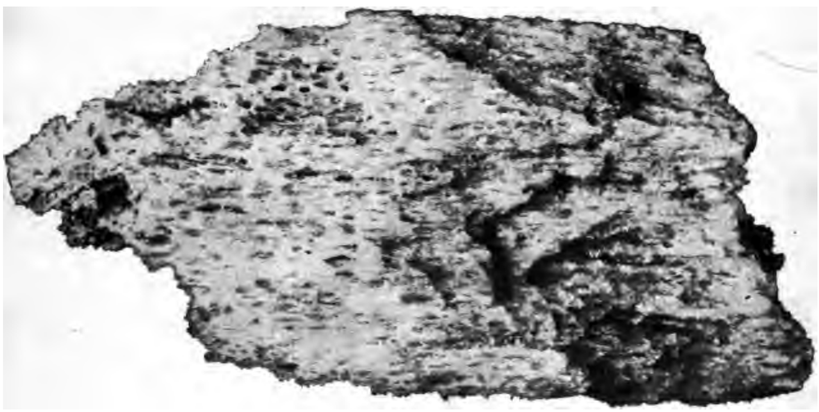
PRACTICE OF COOKING OR BURNING IN MANUFACTURE.

In the process of manufacture of plaster, when sufficient heat is applied the water of crystallization of the gypsum is converted into steam, the crystals are broken up, and the mass boils vigorously. When the temperature reaches about 132° C. the material ceases boiling, settles down in the kettles, and is seen to have a decreased volume as a result of the loss of water. As the temperature rises to 138° to 143° C. the mass again boils, losing more of the water of crystallization. When the temperature reaches about 177° C. the material is withdrawn from the kettles, the process of boiling being checked before a temperature is reached which is sufficiently high to drive off the water of crystallization from the whole mass; in other words, it is stopped when it has approximately the composition of the second hydrate, and before the plaster is dead-burnt, or reduced to anhydrite.

THEORY OF SET OF PLASTER.

If a solution of gypsum is crystallized by evaporation the crystals which form do not interpenetrate, but form a granular mass, which *resembles natural gypsum.* Plaster of Paris, on the addition of water,

A. AGGREGATE OF IMPURE GYPSUM CRYSTALS FROM GYPSEOUS MARL BED.



B. SPONGY GYPSUM FORMED AS A SECONDARY DEPOSIT.

becomes fully hydrated and forms a mass of interpenetrating crystals. These two processes are quite different. The setting of plaster is a chemical process, the stable hydrate being formed from the unstable. In properly burned plaster there are fragments of the original crystals present which form starting points for recrystallization, and as a result a solid body is formed in which the needle-like crystals are interlocked in such a way as to give a good degree of hardness and a fine texture. If the plaster has been underburned it is not completely converted into the unstable hydrate, the gypsum has not been reduced to proper fineness, and in setting crystallization produces a less uniform mass. If, on the other hand, the gypsum is overburned, so that there are no minute fragments or crystals to start the process of recrystallization, it will set slowly and less perfectly. Moreover, overburned plaster consists largely of anhydrite, which takes up water less readily than the unstable hydrate, which is the essential constituent of plaster of Paris.

USE OF RETARDERS.

When water is mixed with plaster of Paris the plaster will set in from six to eight minutes. In order to delay this process and allow time for workmen to use or apply the plaster properly certain substances, known as retarders, are added. The retarders are added in the process of manufacture after the plaster has been burned, and should be thoroughly mixed with it. The amount is varied according to the time which must be allowed for using the plaster. The set may be held back so that it will not be complete until from two to six hours, or even a whole day, has elapsed. The action of the retarders is evidently to interfere mechanically with the process of crystallization, by preventing in a measure the molecular rearrangement of the plaster and to hold back the water which is essential to its hydration. To this end various substances are used, such as organic matter and various mineral substances, or a combination of both. When plaster is manufactured from a secondary deposit of gypsum or gypsite, as it is called, the impurities present may accomplish the retardation to the desired degree. The materials employed as retarders have a wide range in character, and include such substances as tankage from packing houses, glue, glycerin, molasses, sugar, ground peas, beans, or grain, sawdust, pulp, fiber, lime, slag, earths, alkalies, acids, etc., mixed in varying proportions, although some of them may be used singly. The amount employed is small. The patented retarders commonly employed are mixed in the proportion of from 6 to 15 pounds to the ton of plaster. The effect on the texture and strength of the set plaster is very slight, and when substances are used which do not decay, and are employed in small amounts, they do not prove objectionable.

USE OF ACCELERATORS.

When it is desired that plaster should set very quickly certain salts are mixed with it. As an example of the use of accelerators may be cited the addition of a small amount of alum or borax to dental plaster, in order to cause it to set promptly. The effect of the presence of crystals in a mixture of plaster of Paris and water may be seen when a small amount of old plaster has been left in the receptacle in which the mixture is made. The plaster already set starts the crystallization in the mass much sooner than it would otherwise begin.

HARDENING OF PLASTER.

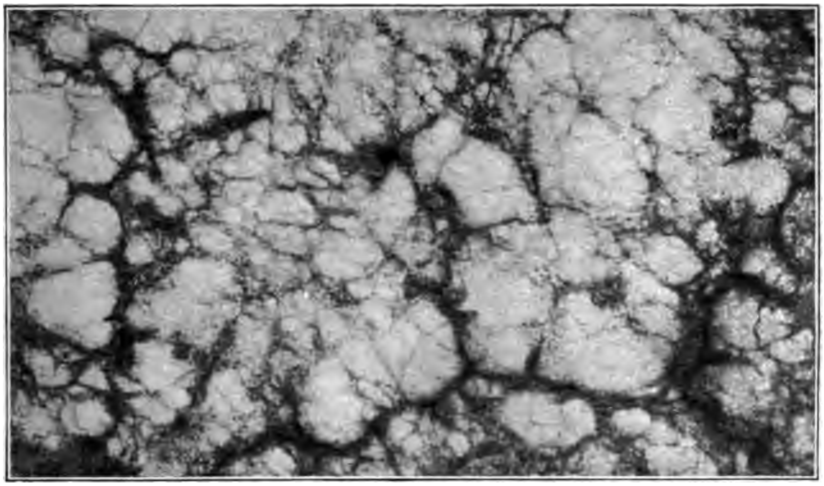
It has been found that by the use of certain chemicals plaster may be rendered harder than when it sets in the natural way. These chemicals may be used either in the process of manufacture or after the plaster has set in the desired form. The hardening depends on the action of the chemicals on the lime carbonate which is present as an impurity in the plaster, converting it into calcium sulphate. In case it is desired to effect this in the manufacture after the plaster has been burned, it is treated with a solution of alum, sulphuric acid, borax, or other chemicals, and reburned at a low heat. If it is desired to harden the plaster after it is set, the surface is sponged with a solution which, entering the material, produces the desired chemical change; or it may be saturated with oil or paraffine, which toughens it and allows it to be polished.

HARDENING OF NATURAL GYPSUM.

By a process similar to that employed in hardening plaster after it has set, gypsum rock is made more durable, so that it can be used as a substitute for marble and other ornamental stones in finishing buildings. It is not employed to any large extent. The process usually consists of heating blocks of gypsum and driving out all the moisture, then allowing them to absorb a solution, after which they are reheated or dried. The result is a slight chemical change in the composition of the rock, giving it a denser texture and greater hardness.

DESCRIPTION OF PROCESSES OF MANUFACTURE.

The process of manufacture of gypsum products varies somewhat in the different parts of the United States, but in all cases follows practically the same methods. There are essentially two classes of plants—those which use gypsum rock, and those which use gypsum earth. The gypsum earth requires much less machinery, since it does not have to be crushed, and can usually be obtained with less labor. The plants which use gypsum earth have the disadvantage of the



A. MASSIVE GYPSUM SHOWING MOTTLED STRUCTURE.

B. MASSIVE GYPSUM SHOWING BANDED STRUCTURE.

deposits being local in character, and consequently being exhausted in the course of a few years. This necessitates the moving of the machinery or the transportation of the gypsum earth. The rock gypsum deposits are usually extensive enough to supply a large mill for many years.

The first step in the manufacture may be called the winning of the crude material. The gypsum earth, or gypsite, is sometimes loose enough to be shoveled directly into wagons or tram cars. In other cases it is loosened with a disk harrow and wheeled away in scrapers. Because of its being quite moist, it is usually allowed to dry under sheds, in order to save the expense which would be entailed in driving off the water, and also because it will pass through the machinery more readily when dry and pulverulent. These deposits seldom have much overburden, and when they must be uncovered the material which overlies them can be moved without the necessity of blasting. The detrital material, such as soil and silt, is usually scraped up and dumped to one side or thrown into the pit. Steam shovels can be used to advantage in these deposits, although the equipment of the plant is seldom so elaborate.

Rock gypsum can be won most advantageously when it is exposed in surface ledges situated in bluffs, for it can then be transported by means of a gravity tram, and the overburden and waste can be disposed of without much handling. Moreover, water does not stand in the quarries, as it frequently does in low ground. Rock gypsum, which is obtained at low levels, usually is quarried until the overburden is too great to be removed economically. After this it is mined. Pillars are left to support the roof, but in some cases timbering is resorted to, especially where the roof is weak. In the localities which have been worked for many years extensive underground workings have been made, and it is found advantageous to resort to shafts rather than to long hauls by means of trams. Considerable care is required in selecting the purer portions of the beds when they vary in composition. The impure grades of gypsum are sometimes utilized for land plaster.

Rock gypsum is usually delivered at the mill in pieces of convenient size for handling. It is then passed through crushers, which are essentially heavy jaws of chilled iron having a backward and forward motion. By means of them the rock is reduced to sizes which can be fed into a gyratory crusher. There are various styles of this machine, but they are all essentially of a pattern similar to a coffee mill, and they reduce the material to small fragments. The gypsum is next ground to a coarse powder by means of buhrs. For this operation buhrstones or rolls, such as are used in flour mills, are commonly employed. Special forms of machinery, known as disintegrators, have been invented. They consist of cages with short crossbars that travel in opposite

directions and beat the rock into a powder by impact. The gypsum is next conveyed to the calcining kettles. These are of cylindrical shape, and are placed vertically within a jacket of brick or masonry work. The heat is applied from below, and there are usually flues which pass through the kettles. In the process of cooking the kettles are filled gradually, and the mass is stirred by means of revolving arms, which prevent the burning of the gypsum at the bottom of the kettle and also serve to distribute the heated material so that the mass has an even temperature. When the gypsum begins to cook, the water which is driven off causes it to boil vigorously. This boiling ceases when the temperature has reached about 132° C., and the mass settles a few inches in the kettles, as the result of the loss of water. As the temperature rises the gypsum boils once more, but less vigorously. At a temperature of about 177° C. the material is drawn off by opening a gate at the bottom of the kettle. It falls into a fireproof bin, or onto a floor, where it is allowed to cool.

In the process of cooking the temperature is noted by means of a thermometer inserted into the mass or placed within a tube which reaches into the kettle. Expert calciners, however, are able to judge the stage of the process by noting the appearance of the gypsum and the progress of the operation, which is conducted in a relatively uniform manner. In the first boiling of the gypsum the material is reduced to the condition of the second hydrate. In the second stage of boiling it is partially converted into anhydrite. It is essential for the manufacture of a good product that this should be checked at the right time, since if it is carried too far it is dead burned and will not set readily.

After the gypsum has been cooked and cooled it is bolted or passed through screens. Sometimes it is reground to a finer powder; otherwise the lumps and coarser portions are returned and worked a second time. The finished product is either stored or placed directly in hundred-pound jute or paper sacks or in barrels.

The best arranged plants are so constructed as to convey the gypsum by means of gravity spouts from the time that it enters the mill until it issues from the buhrs, and sometimes until it issues from the kettle. After is has reached a state of fineness which will permit of the operation, it can be conveyed by means of blowers. In other cases bucket elevators, or belt conveyors, are employed in raising it into bins, from which it is drawn off by gravity spouts.

When retarders are added they are mixed after the gypsum has been cooked and cooled. This is often done at the mill where the plaster is manufactured, but there are many firms in the United States which purchase calcined plaster and convert it into special brands of wall finish in their own mills. Sometimes, in addition to the retarder, kiln-dried sand and hair or other fiber is added in proportions which require

A. GYPSUM HAVING SERRATE SURFACE DUE TO RAIN EROSION.

B. ROCK GYPSUM WHICH SHOWS EFFECTS OF SOLUTION.

simply the addition of water in preparing it for wall mortar. Plaster to which retarders have been added should not be stored for a long time, especially when the retarder consists of substances liable to decompose, or change chemically. It is also essential that moisture should be excluded, so that the plaster will not become hydrated.

The preparation of the finer grades of plaster of Paris and the manufacture of quick-setting plasters, such as dental plasters and special grades used in the arts, require a pure quality of gypsum and specific treatment of it. The simplest operation in the industry is the manufacture of land plaster, which requires only the grinding of the raw material.

In the earliest process gypsum was baked in ovens. This method is still in vogue in Germany and other European countries, but has been materially modified, so that it can be conducted on an extensive scale. It is considered necessary in the manufacture of certain grades of plaster, especially that used in forming the molds employed in the making of porcelain, to have the gypsum uniformly calcined. Accordingly it is baked in ovens, since this method insures a more uniform heat.

American manufacturers are careful in cooking gypsum not to dead-burn it, which renders it too slow-setting. In the German industry slow-setting plaster is largely in use. It requires more careful and extensive treatment in applying it, but it is claimed that its greater hardness renders it suitable for certain purposes for which ordinary American wall plasters can not be used. In this country Portland cement commonly takes its place, yet some manufacturers are producing gypsum-cement plasters which have a good degree of hardness and approach the German grades of slow-setting plaster. The Germans employ in the manufacture of this grade a vertical kiln very similar in construction to an ordinary limekiln. The fireplace is so arranged that the ashes fall into a pit and the flames and heat pass upward through the mass of gypsum. As the gypsum is burned the lower portion, when sufficiently calcined, is drawn off back of the grate, and the remaining mass settles down in the kiln. The process is accordingly a continuous one, and since there is no need of guarding against dead-burning in the manufacture of this grade, the process is satisfactory.

German manufacturers are to be credited with having made the greatest advance toward perfecting a continuous process for the manufacture of the ordinary grades of calcined plaster. When vertical kettles are used considerable time is required in filling and drawing off. To obviate this rotary kilns have been introduced, which are similar to those used in calcining Portland cement. There are, however, some differences in the process of burning gypsum and cement. A reducing flame must not be allowed to come in contact with the

gypsum, since it would partially reduce it to calcium sulphide, which will not set. Moreover, the gypsum should not be discolored by soot or flame. Accordingly a blast of hot air is used instead of the direct blast of the furnace.

A method of cooking by means of superheated steam has been invented, but while the principle is an excellent one, the process has not been sufficiently perfected, and the expense of fuel is relatively greater.

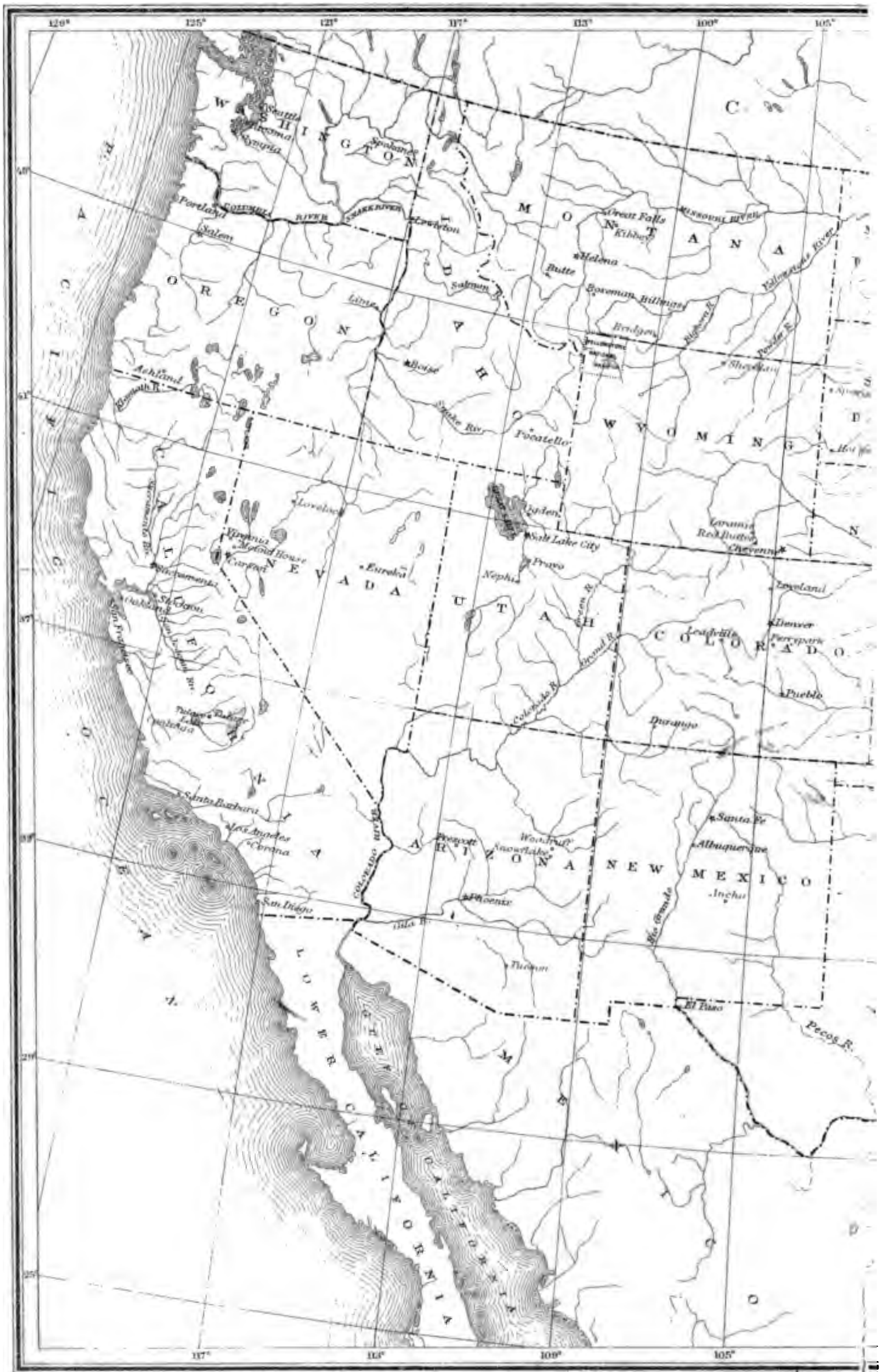
HISTORICAL SKETCH OF THE GYPSUM INDUSTRY.

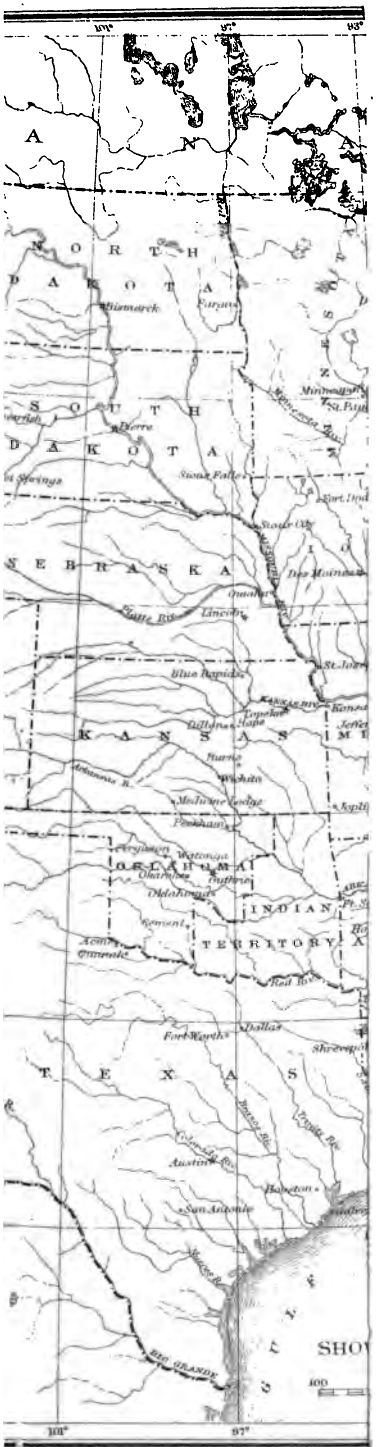
The first deposits which were utilized in the United States were those in New York. This was at a time when the population was largely confined to the Atlantic coast. As settlement extended, the gypsum in Virginia, Ohio, and Michigan was developed, and later, that in Iowa, Kansas, and the Western States. On the Pacific slope the industry was at first largely confined to California. The deposits in the western part of the country are relatively more extensive than in the eastern, but the industrial conditions at the present time are not such as to create a demand for the material. The statistics which are available for the early period show that in New York, Virginia, Ohio, and Michigan the manufacture of land plaster was an important branch of the gypsum industry. This was due to the theories of numerous writers on agriculture, which were printed in the newspapers of the early times, and which called attention to the beneficial effects of land plaster in restoring the fertility of worn-out land. While the use of land plaster has continued to be of about the same importance, the demand for wall plaster has greatly increased. This is due to the perfecting of the processes of manufacture, and to the growing demand for strong material in modern architecture. It is the use of gypsum as wall plaster which has led to the development of the deposits in the Western States, such as Iowa, Kansas, Oklahoma, and Texas, where the soil still retains its natural fertility.

USES OF GYPSUM.

Probably the first use made of gypsum was as plaster of Paris. Its application in the arts has been extended until it is now one of the important structural materials and is essential in many industries. Calcined gypsum may be classified as plaster of Paris and wall plaster. There are many special grades which are prepared for particular uses, but they are not enumerated here, since the names by which they are known in the market are largely trade or patented names. Plaster of Paris is used principally in modeling, and in forming molds and plaster ornaments, especially such as are used in interiors. By treating casts they may be made to withstand the weather, but in the United States terra cotta is more commonly used for exteriors. The use of plaster

U. S. GEOLOGICAL SURVEY





101°
97°
93°
NORTH DAKOTA
Bismarck
Fargo
SOUTH DAKOTA
Pierre
Sioux Falls
Minnesota R.
Sioux City
Des Moines
NEBRASKA
Omaha
Lincoln
Platte R.
Blue Rapids
KANSAS
Topeka
Wichita
Arkansas R.
Medicine Lodge
Watonga
OKLAHOMA
Guthrie
INDIAN TERRITORY
Red R.
Fort Worth
Dallas
TEXAS
Brazos R.
Trinity R.
Colorado R.
Austin
Houston
San Antonio
RIO GRANDE
101°
97°

RARY
anford, Jr.

of Paris as molds in the manufacture of porcelain is extensive, and in the plate-glass industry thousands of tons are required annually for bedding the glass during the process of grinding and polishing. It is also employed as a filler in paper and as a minor constitutent of some Portland cements. Some raw gypsum is used as a body for paint. Calcined gypsum prepared with glue and pigments is applied as a thin plaster to walls. This preparation is sometimes called alabastine. The use of gypsum as wall plaster is the most extensive one, and because of its adaptability it has largely displaced lime and sand mortar as wall finish. It is not improbable that the use of slow-setting plaster, having a greater degree of hardness, may be extended more widely, as has been the case in Germany.

Ground gypsum is sometimes found as an adulterant in flour, and enters surreptitiously into many products. In agriculture ground gypsum has two uses. The more important one is as land plaster, for increasing the fertility of soils. Its action is not clearly understood, being one of the many unsolved problems relating to soil and its fertility. The theory is that in its decomposition and reaction with elements of the soil, potash is freed, which is needed by plants. Accordingly, soils which contain soluble potash in abundance would not be benefited by the application of gypsum. In the Western States there is considerable land which contains black alkali, or which upon being irrigated develops this substance in excess, so that it is injurious to the crops. Black alkali is a term applied to the carbonates of soda, potash, and magnesia. It may be neutralized by the application of land plaster to the soil. The chemical reaction which takes place is the change of carbonates to sulphates, which are less injurious to plants.

STATISTICS.

PRODUCING LOCALITIES.

During 1902 gypsum was produced in the following States and Territories: Michigan, Iowa, Texas, New York, Ohio, Kansas, Oklahoma, California, Wyoming, Colorado, Virginia, Utah, Montana, South Dakota, Nevada, and Oregon. The producing localities are shown on the accompanying map of the United States (Pl. VI). From an inspection of the map it will be seen that the industry is well distributed, excepting in the southeastern part of the United States. In that region there are some deposits of gypsum known, but they are usually not important enough to justify extensive operations. The deposits in Florida, described elsewhere in this report, may prove to be of economic value.

At some of the localities the deposits have been worked for many years, at others they have just been opened; and in the newer parts of the country the industry is just established. At a number of localities in New York gypsum is quarried for land plaster, but from these

the production is small. Previous to 1902 gypsum was produced at a few localities which are now abandoned, either because of the exhaustion of the readily available material or because they were not advantageously situated with respect to market.

PRODUCTION BY CLASSES OF PRODUCT.

The production of gypsum is reported as crude gypsum, land plaster, plaster of Paris, and wall plaster, which represent the conditions in which gypsum first reaches the market. The quantity and value of each of these classes and the totals for 1902 are set forth in the following table. For the sake of comparison the production for 1901, somewhat differently classified, is also given below. The total production is estimated as crude, while the total value is that of the product as it first reaches the market.

Production, value, and prices of gypsum in the United States, 1902.

Grade.	Quantity.	Value.	Average price per ton.
	Short tons.		
Crude	81,455	$93,914	$1.15
Land plaster	60,791	106,237	1.75
Plaster of Paris	188,702	562,928	2.98
Wall plaster	350,685	1,326,262	3.78
	[a] 816,478	2,089,341	....

[a] Estimated as crude.

Production, value, and prices of gypsum in the United States, 1901.

Grade.	Quantity.	Value.	Average price per ton.
	Short tons.		
Crude	68,669	$71,773	$1.05
Land plaster	59,058	109,551	1.85
Calcined	399,686	1,325,317	3.31
	[a] 633,791	1,506,641	....

[a] Estimated as crude.

PRODUCTION BY STATES.

The production by States during 1901 and 1902 is shown in the following table. In order to avoid giving the product of individual plants, it has been necessary in some instances to combine the production of two or more States.

Production and value of gypsum in the United States in 1901, by States.

State.	Total product.	Sold crude.		Ground into land plaster.	
		Quantity.	Value.	Quantity.	Value.
	Short tons.	*Short tons.*		*Short tons.*	
California	3,550	3,550	$4,200	....	....
Colorado and Wyoming	17,394	150	150	16	$62
Iowa, Kansas, and Texas	213,419	2,750	3,575	3,079	5,025
Michigan	185,150	46,086	47,986	9,808	10,708
New York	119,565	11,678	10,908	33,591	61,093
Oklahoma	15,930	....	....	....	....
Virginia	15,236	1,054	1,104	9,675	25,995
Other States	63,547	3,401	3,850	2,889	6,668
Total	633,791	68,669	71,773	59,058	109,551

State.	Calcined into plaster of Paris.			Total value.
	Before calcining.	After calcining.	Value.	
	Short tons.	*Short tons.*		
California	....	....	....	$4,200
Colorado and Wyoming	17,228	13,595	$76,223	76,435
Iowa, Kansas, and Texas	207,590	164,720	620,736	629,336
Michigan	129,256	103,933	208,549	267,243
New York	74,296	55,273	169,668	241,669
Oklahoma	15,930	13,205	66,031	66,031
Virginia	4,507	3,752	18,045	45,144
Other States	57,257	45,208	166,065	176,583
Total	506,064	399,686	1,325,317	1,506,641

Production and value of gypsum in the United States in 1902, by States.

State.	Total product.	Sold crude.		Ground into land plaster.	
		Quantity.	Value.	Quantity.	Value.
	Short tons.	*Short tons.*		*Short tons.*	
California, Ohio, and Virginia	101,545	2,360	$6,790	16,357	$35,450
Colorado and Wyoming	16,051	----	----	----	----
Iowa, Kansas, and Texas	295,769	957	1,180	4,331	6,497
Michigan	240,227	68,885	70,460	13,022	16,340
New York	110,364	9,153	15,184	25,981	43,750
Oklahoma	34,156	----	----	----	----
Other States	18,366	100	300	1,100	4,200
Total	816,478	81,455	93,914	60,791	106,237

State.	Calcined into wall plaster and plaster of Paris.			Total value.
	Before calcining.	After calcining.	Value.	
	Short tons.	*Short tons.*		
California, Ohio, and Virginia	82,828	66,263	$248,153	$290,393
Colorado and Wyoming	16,051	12,841	73,372	73,372
Iowa, Kansas, and Texas	290,481	232,385	799,678	807,355
Michigan	158,320	126,656	372,821	459,621
New York	75,230	60,184	200,236	259,170
Oklahoma	34,156	27,325	111,215	111,215
Other States	17,166	13,733	83,715	88,215
Total	674,232	539,387	1,889,190	2,089,341

The statistics of production by States are relatively complete since the Eleventh Census. The following table shows the production from 1890 to 1900:

Production and value of gypsum, by States, 1890–1900.

State.	1890.		1891.		1892.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Short tons.		*Short tons.*		*Short tons.*	
California	4,249	$29,178	3,000	$36,360		
Colorado	4,580	22,050	4,720	19,400	1,500	$1,500
Iowa	20,900	47,350	31,385	58,095	12,000	28,500
Kansas	20,250	72,457	40,217	161,322	46,016	195,197
Michigan	74,877	192,099	79,700	223,725	139,557	306,527
New York	32,903	73,093	30,135	58,571	32,394	61,100
Ohio	12,748	87,533	9,123	36,586	13,275	49,521
South Dakota	2,900	7,750	3,615	9,618		
Texas					1,926	8,640
Utah			3,000	15,000	2,600	16,300
Virginia	6,350	20,782	5,959	22,574	6,991	28,207
Wyoming	3,238	22,231	1,992	6,200		
Total	182,995	574,523	212,846	647,451	256,259	695,492

State.	1893.		1894.		1895.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Short tons.		*Short tons.*		*Short tons.*	
California			6	$30	5,158	$51,014
Colorado			895	4,800	1,371	8,281
Indian Territory					13,100	46,125
Iowa	21,447	$55,538	17,906	44,700	25,700	36,600
Kansas	43,631	161,599	64,889	301,884	72,947	272,531
Michigan	124,590	303,921	79,958	189,620	66,519	174,007
Montana			175	1,820		
New York	36,126	65,392	31,798	60,262	33,587	59,321
Ohio	11,646	39,884	20,827	69,597	21,662	71,204
Oklahoma			1,300	7,500		
South Dakota	5,150	12,550	4,295	16,050	6,400	20,600
Texas	4,011	13,372	6,925	27,300	10,750	36,511
Utah			1,920	12,225	2,134	11,484
Virginia	7,014	24,359	8,106	24,431	5,800	17,369
Wyoming			312	1,500	375	2,400
Total	253,615	696,615	239,312	761,719	265,503	807,447

Production and value of gypsum, by States, 1890–1900—Continued.

State.	1896.		1897.		1898.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Short tons.		*Short tons.*		*Short tons.*	
Arizona			30	$250	30	$700
California	1,452	$11,738	351	2,774	3,800	24,977
Colorado	1,600	10,547	1,575	10,305	165	726
Indian Territory	8,000	24,000	10,734	40,050		
Iowa	18,631	34,020	29,430	64,900	24,733	45,819
Kansas	49,435	148,371	54,353	189,679	59,180	191,389
Michigan	67,634	146,424	94,874	193,576	93,181	204,310
Montana	385	1,940	425	2,300	1,123	7,272
New York	23,325	32,812	33,440	78,684	31,655	81,969
Ohio	22,634	63,583	18,592	50,856	21,303	61,884
Oklahoma					3,150	12,000
Oregon					150	450
South Dakota	6,115	20,000	8,350	19,240	2,740	9,200
Texas	16,022	48,070	24,454	65,651	34,215	58,130
Utah	2,866	13,600	2,700	13,500	2,610	10,080
Virginia	5,955	17,264	6,374	16,899	8,378	23,388
Wyoming	200	975	3,300	7,200	5,225	22,986
Total	224,254	573,344	288,982	755,864	291,638	755,280

Production and value of gypsum, by States, 1890-1900—Continued.

State.	1899.		1900.	
	Quantity.	Value.	Quantity.	Value.
	Short tons.		*Short tons.*	
Arizona	47	$1,200	35	$900
California	2,950	14,950	3,280	10,088
Colorado	871	3,904	967	5,300
Indian Territory	12,000	26,000	6,500	15,000
Iowa	75,574	296,220	184,600	561,588
Kansas	85,046	247,690	48,636	150,588
Michigan	144,776	283,537	129,654	285,119
Montana	582	3,698	1,025	7,980
New York	52,149	105,533	58,890	150,588
Nevada	....	....	1,000	4,805
Ohio	27,205	73,520	39,034	119,946
Oklahoma	11,526	36,600	18,437	60,380
Oregon	550	1,895	550	1,710
South Dakota	550	4,000	2,050	13,800
Texas	53,773	125,000	80,622	192,418
Utah	2,352	10,240	2,397	4,984
Virginia	11,480	32,043	11,940	18,111
Wyoming	4,804	21,050	4,845	24,229
Total	486,235	1,287,080	594,462	1,627,203

IMPORTS.

From the following tables it will be seen that a large amount of gypsum is imported annually. It comes principally from Nova Scotia and New Brunswick and enters the ports of the Atlantic coast. Next in importance is the amount received from the peninsula of Lower California, Mexico, which enters at the port of San Francisco. The gypsum is usually shipped crude and is calcined in mills at the place of entry. Some of the imported material consists of the finer grades of plaster of Paris.

Imports of crude, ground, or calcined (dutiable) gypsum, by countries.

Country from which imported.	1902.		1901.		1900.	
	Tons.	*Value.*	*Tons.*	*Value.*	*Tons.*	*Value.*
France	132	$1,902	185	$1,311	342	$2,397
United Kingdom	190	1,854	93	987	59	836
Nova Scotia and New Brunswick	259,353	275,877	196,932	216,636	203,347	234,563
Mexico			2,236	9,700	1,014	4,500
Other countries	20	23	1	36	88	602
Total	259,695	279,656	199,447	228,670	204,850	242,898

Imports of crude, ground, or calcined (dutiable) gypsum, by customs districts.

Customs district into which imported.	1902.		1901.		1900.	
	Tons.	*Value.*	*Tons.*	*Value.*	*Tons.*	*Value.*
Aroostook, Me	57	$148	415	$796	290	$448
Bangor, Me	235	141	390	234	153	92
Bath, Me	703	429	740	446	736	966
Passamaquoddy, Me	8,395	7,628	8,232	7,942	9,503	10,530
Portland and Falmouth, Me			180	135		
Boston and Charlestown, Mass	5,760	11,546	5,921	11,118	6,450	11,925
Gloucester, Mass	235	144	230	141		
Fairfield, Conn	360	990	315	866	284	688
New Haven, Conn	3,515	3,124	1,916	1,325	3,942	2,818
New York, N. Y	157,699	167,444	117,989	138,565	121,728	150,074
Newark, N. J	30,388	35,091	19,700	21,751	21,491	22,857
Perth Amboy, N. J	6,218	3,733	2,780	1,661	4,230	2,538
Philadelphia, Pa	33,343	39,471	23,900	25,233	21,216	25,828
Delaware	1,630	960	1,387	816	2,325	1,401
Baltimore, Md	3,987	3,040	5,635	3,381	3,822	2,834
Norfolk and Portsmouth, Va	5,600	4,815	7,480	4,488	5,715	3,746
Alexandria, Va	1,550	930			2,000	1,320
San Francisco, Cal			2,236	9,700	1,014	4,500
Other districts	20	22	1	72	32	333
Total	259,695	279,656	199,447	228,670	204,850	242,898

GYPSUM DEPOSITS IN NEW YORK.

By Edwin C. Eckel.

CHARACTER AND EXTENT.

The gypsum in New York State occurs as rock gypsum interbedded with shales and shaly limestones. Several gypsum beds, separated by shales, usually occur in any given section. They are lenticular in shape, but of such horizontal extent that in any quarry they are usually of uniform thickness. Those that are worked vary from 4 to 10 feet in thickness in most of the quarries, but at Fayetteville a 30-foot bed is exposed. The area in which the gypsum-bearing formations are found (see Pl. VII) extends through the central part of the State, the productive portion of the belt including parts of Madison, Onondaga, Cayuga, Ontario, Genesee, Monroe, Livingston, and Erie counties.

Most of the deposits are too impure to be used in the manufacture of the finer grades of plaster of Paris, since they contain small amounts of earthy matter, lime, and iron. Until recently almost all the product was marketed as land plaster. Within the last few years, however, several large plants have commenced the manufacture of calcined plaster and wall plaster. The gypsum used in these plants is mostly obtained from Genesee County, where it seems to be of a higher grade than that which occurs farther east.

ECONOMIC DEVELOPMENT.

In the early history of the State gypsum was employed extensively as a fertilizer. This was largely due to the publicity given to its use by the numerous papers on the subject written by early authorities on agricultural topics. The development of the deposits exercised an appreciable influence on the gypsum industry of the United States, and led to exploration for it in other places.

Gypsum in New York is generally quarried at points where the overlying rocks have been thinned or entirely removed by erosion. In the area of the State where the deposits occur there is usually a thick covering of glacial drift, which disguises the bed rock and makes it difficult to discover the gypsum beds. At many of the localities the gypsum is obtained by quarrying. At a few places the beds have been followed under cover for some distance, the opening constituting a small mine, rarely more than 1 or 2 acres in extent. Where the material is obtained by this method the workings are timbered, or pillars

of gypsum are left at intervals to support the roof. The rock is hoisted by cars operated by steam or drawn by horses. Occasionally in the workings places are found where the gypsum has been removed by solution, producing a sink, which has been filled by surface material which has fallen in.

The deposits are so extensive and so widely distributed that those which are favorably situated with respect to transportation facilities are abundantly capable of supplying the demand. Most of the openings which supply land plaster are located in the vicinity of the Erie Canal, or some of its branches, which affords a cheap means of transportation. The larger plants, especially those which manufacture calcined plaster, also have convenient railway facilities.

The most easterly points at which gypsum has been worked are in Madison County, but the quantity produced there is small—just sufficient to supply the local demand for land plaster. In Onondaga County, at Marcellus, Fayetteville, and other places, large quarries are worked, part of the material being calcined and part ground for land plaster. The quarries near Union Springs, in Cayuga County, produce principally land plaster, as do those of Phillipsport, Gibson, and Victor, in Ontario County. At Mumford and Oakfield, however, there are large quarries and plants which produce calcined plaster. Most of the gypsum obtained in western Genesee County and in Erie County is used locally as land plaster.

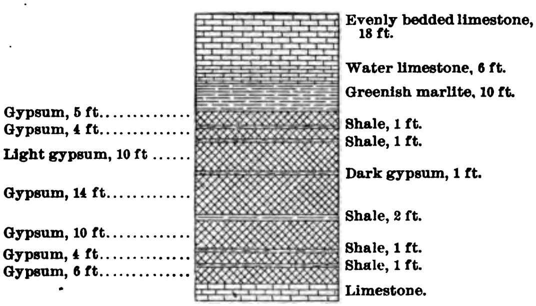


FIG. 2.—Section at Hurd gypsum mine, Linden, N. Y.

GEOLOGIC RELATIONS.

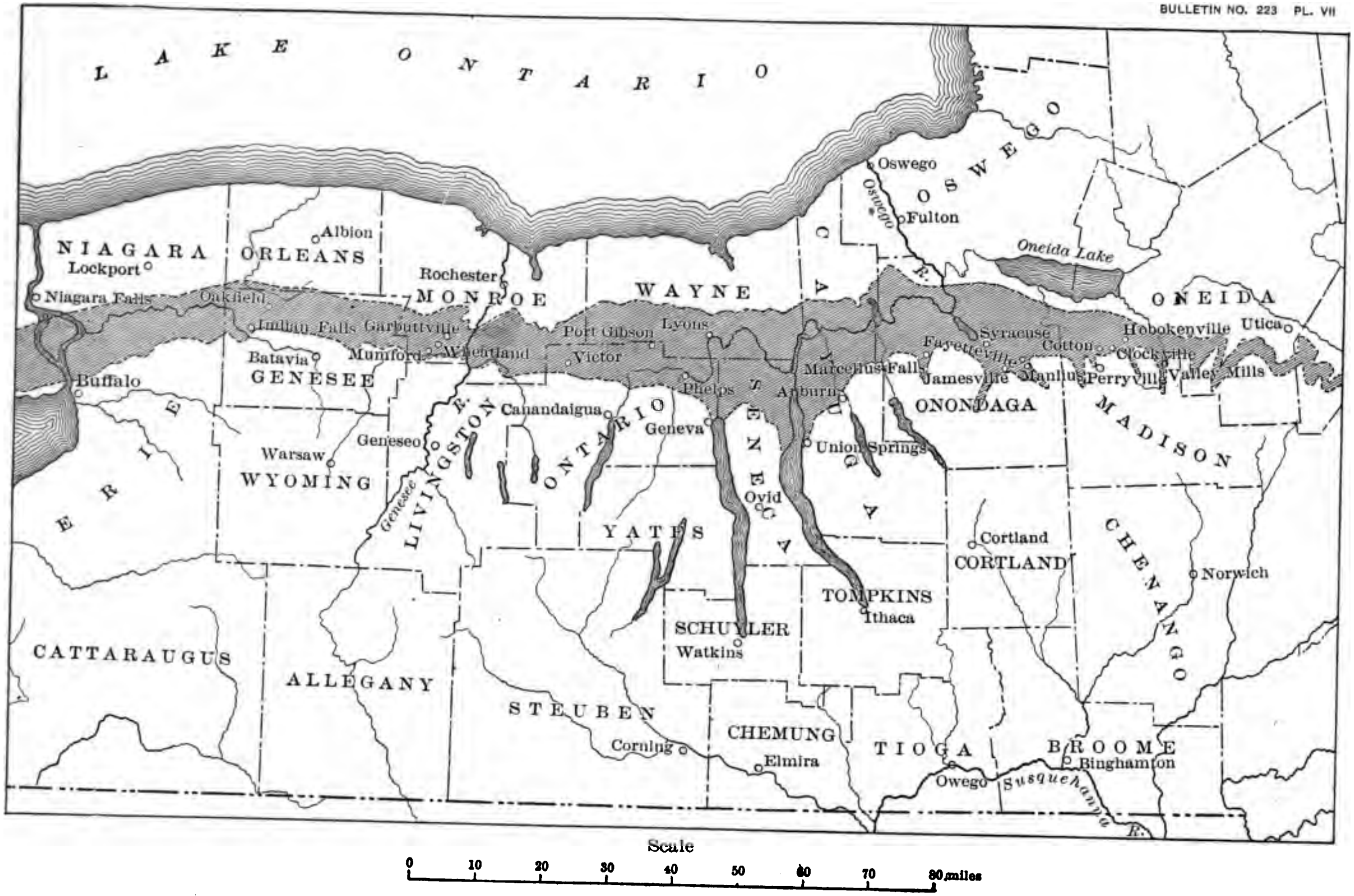
The gypsum-bearing formation occurs in a series of shales and shaly limestones of Upper Silurian age. This series is called the Salina group. It is divisible in Onondaga County, where it has been studied in detail, into four parts. Beginning with the highest, these are:

1. Magnesian limestones; argillaceous and with interbedded shales; utilized in the manufacture of natural cement in Erie County.

2. Gypsum beds, shales, and occasional beds of impure limestone.

3. Mottled red and green shales; shales with local, very small quantities of gypsum. This division carries the rock-salt beds of New York State, but owing to its ready solubility the salt is never seen in natural outcrop, being reached only by shafts or drill holes.

4. Red shales; a thick series of red shales forming the base of the



MAP SHOWING AREA OF SALINA GROUP IN CENTRAL NEW YORK AND GYPSUM-PRODUCING LOCALITIES.

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Salina group in Onondaga County. In going westward, however, these red shales rapidly diminish in thickness and disappear entirely before the western border of Wayne County is reached.

The main gypsum deposits occur in the upper part of the Salina, as is noted in the divisions above outlined. The smaller occurrences in the lower horizons are of no economic importance. The association of the salt beds of this group at horizons below the gypsum is of interest, since it has a bearing upon the origin of the deposits, which are regarded as having been derived from water concentrated in inclosed basins, the concentration having been produced by evaporation.

The areal distribution of the rocks of the Salina group is shown on Pl. VII, taken from the new geologic map of New York State. No

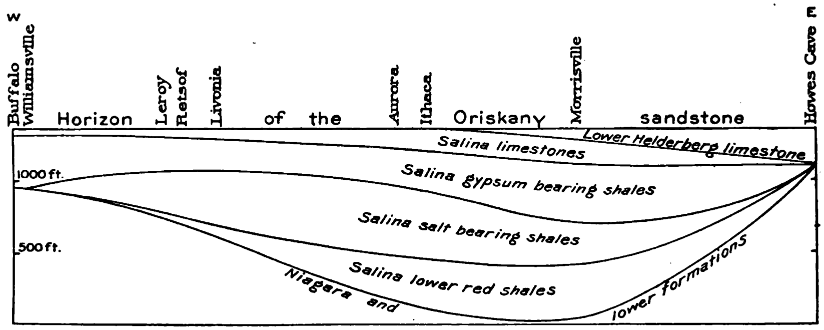


FIG. 3.—Section from east to west showing relations of Salina group in New York.

attempt has been made to show the four divisions of the group. It may be said in general that the gypsum outcrops along a line drawn a short distance north of the southern boundary of the Salina. The dip of the formations in this part of the State is generally to the south, at a low angle. Exposures and well sections, however, show that this dip is not continuous, but is reversed at intervals, giving local dips to the north. Cross folding is very marked in certain parts of the area, giving strong local dips to the east and west. The Salina beds, as a whole, have the form of an irregular lens, being thickest in the meridian of Ithaca, from which place they diminish in thickness westward and eastward (fig. 3). This fact has been demonstrated by plotting the sections as revealed by records of numerous drill holes.

GYPSUM DEPOSITS IN VIRGINIA.

By Edwin C. Eckel.

CHARACTERS AND EXTENT.

All the workable gypsum deposits of Virginia occur in Washington and Smyth counties, in the valley of the North Fork of Holston River. The area within which the known deposits are located is a narrow belt about 16 miles in length, extending from a short distance southwest of Saltville to a point about 3 miles west of Chatham Hill post-office.

The material occurs as rock gypsum, interbedded with shales and shaly limestones of Carboniferous age. The beds of gypsum average 30 feet in thickness at the localities at which they are now worked. The rocks of the district dip at a high angle, however, usually between 25° and 45°, so that certain wells which have been drilled are in the gypsum for long distances, and accordingly immense thicknesses of gypsum have been erroneously reported, because the inclination of the deposits was not taken into account. Near Saltville the dip of the gypsum beds which are worked is toward the northwest; at the mines farther up the valley the dip is to the southeast.

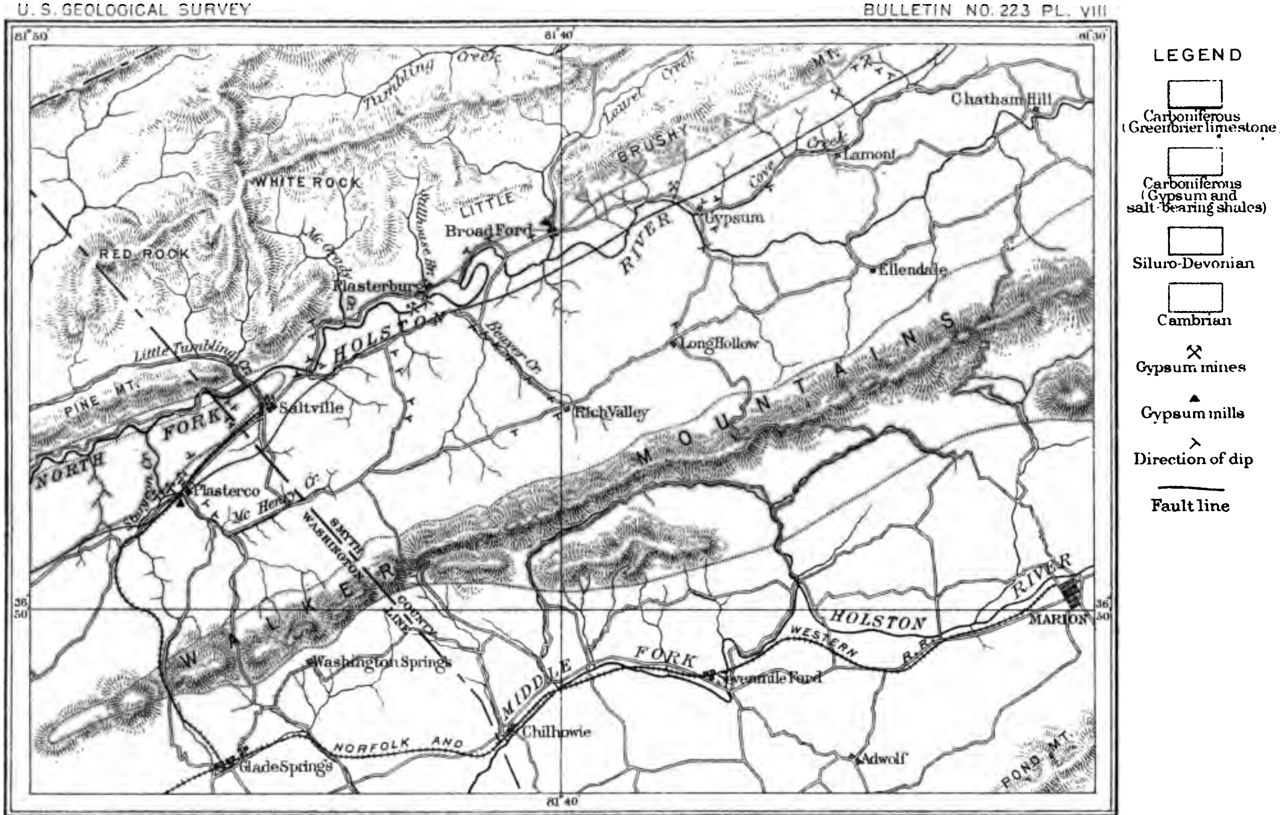
The Virginia gypsum, as shown by several analyses, is of remarkable purity, comparing favorably with that from Nova Scotia.

ECONOMIC DEVELOPMENT.

The development of the gypsum industry in this area has been governed almost entirely by the transportation facilities. The deposits in the upper valley, though extensive and easily workable, have not been largely exploited, owing to the long wagon haul necessary. The deposits at Saltville and Plasterco, which are on a branch of the Norfolk and Western Railroad, have furnished the principal output.

Throughout the entire area the dip of the gypsum beds is so high as to require mining, except at the commencement of the working.

The mines of the Buena Vista Plaster Company south of Saltville are the most extensive, exploitation having been carried to a depth of 280 feet, and the lateral workings extending several hundred yards from the main incline. Timbering is used in places, but the principal reliance is on large gypsum pillars left at intervals. The gypsum is hoisted up the incline by a cable operated by steam power. The product is marketed partly as land plaster and partly as calcined and wall plasters.



MAP SHOWING THE GYPSUM DEPOSITS IN SOUTHWESTERN VIRGINIA, NEAR SALTVILLE
BY EDWIN C. ECKEL

Scale
1 ½ 0 1 2 3 4 miles

JULIUS BIEN & CO. N.Y.

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Openings near Saltville now filled with water were worked until 1902 by a company which utilized the product in the manufacture of Keene's cement[a] at Glade Spring. Farther up the valley gypsum is mined on the property of John Barnes east of Laurel Creek, most of the product being ground for land plaster at a custom mill located on Laurel Creek.

The exposures covering the largest surface area are those on the Buchanan property, between 1 and 2 miles north of Lamont post-office. The product is used entirely as land plaster, part being shipped in lump and part crushed at the custom mill above mentioned.

GEOLOGIC RELATIONS.

The gypsum beds of southwestern Virginia occur interbedded with a series of shales and shaly limestones of Carboniferous age. Under-

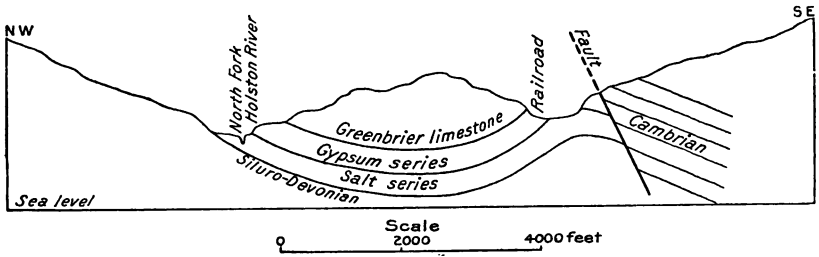

FIG. 4.—Section across Holston and Saltville valleys on a northwest-southeast line midway between Saltville and Plasterco, Va.

lying this gypsiferous series is a thick group of shales carrying heavy beds of rock salt. Overlying the gypsum-bearing shales is the Greenbrier limestone.

Throughout most of the region in question all these beds dip at angles of 25° to 45° SE. Near Saltville, however, a syncline is shown, capped by Greenbrier limestone. All the gypsum obtained at present in the vicinity of Saltville and at Plasterco station is from openings worked on the southeastern side of this syncline, and therefore the beds which are worked in this part of the district dip to the northwest.

A short distance southeast of the line of gypsum outcrops a fault has brought the Cambrian limestone up against the shaly limestones of the Carboniferous. No gypsum need be expected east of this fault line; but it is probable that exploration would show its presence at many points west of the fault line, between the localities now known and worked.

The geologic map accompanying this paper (Pl. VIII) is based on that published in 1884 by Prof. J. J. Stevenson,[b] with slight revision and addition of gypsum localities from field work by the writer.

[a] Engineering News, vol. 49, pp. 107-108.

[b] Trans. Am. Phil. Soc., vol. 22, pp. 114-161.

GYPSUM DEPOSITS IN OHIO.

By S. V. PEPPEL.

CHARACTER AND EXTENT.

The gypsum deposits of Ohio which are of economic value consist of beds of rock gypsum. They have been known since the first settlements were made on the northern shore of Sandusky Bay. The exposures lie at about the level of the waters of the bay, in some places rising a few feet above it. In addition to the deposits of economic importance, gypsum is found in small pockets and isolated bodies throughout the area of the Rondout (Waterlime) formation, which occurs extensively in northwestern Ohio. The deposits which are worked vary considerably in thickness, ranging from a few inches up to 9 feet. On the north shore of Sandusky Bay, in Portage Township, Ottawa County, 1,500 to 2,000 acres of land have been thoroughly prospected with a core drill, and it has been shown that there are from 150 to 200 acres of workable gypsum. On the south shore of the bay, about 2½ miles northwest of the town of Castalia, drilling has shown the presence of another area of workable gypsum, but no developments have yet been undertaken. It is estimated that at the present rate of production the known deposits will last about twenty-five years.

The records of deep wells in other sections of the State have shown the presence of gypsum at a number of places. Prof. Edward Orton,[a] in discussing the gypsum-bearing formation of the State, says:

> At various other points gypsum is found in the outcrops of the formation, and notably in the vicinity of Sylvania, Lucas County, while in the deep wells recently drilled through northern and central Ohio it is the exception to miss deposits of gypsum in the samples of drillings. The last case reported is 3 feet of pure fibrous gypsum from a depth of 150 feet at Upper Sandusky.
>
> In the deep well drilled in 1886 at Sandusky a bed 9 feet in thickness was reported by the driller at a depth of 272 feet. It was also reported in smaller amounts at other points in the next 800 feet of rock passed through by the drill.

The principal ledges of gypsum which are worked are of a grayish cast, due to the numerous fine wavy bands of carbonaceous material which run through it. There are occasionally thin shaly partings, having irregular courses through the gypsum rock. The gypsum itself is pure white.

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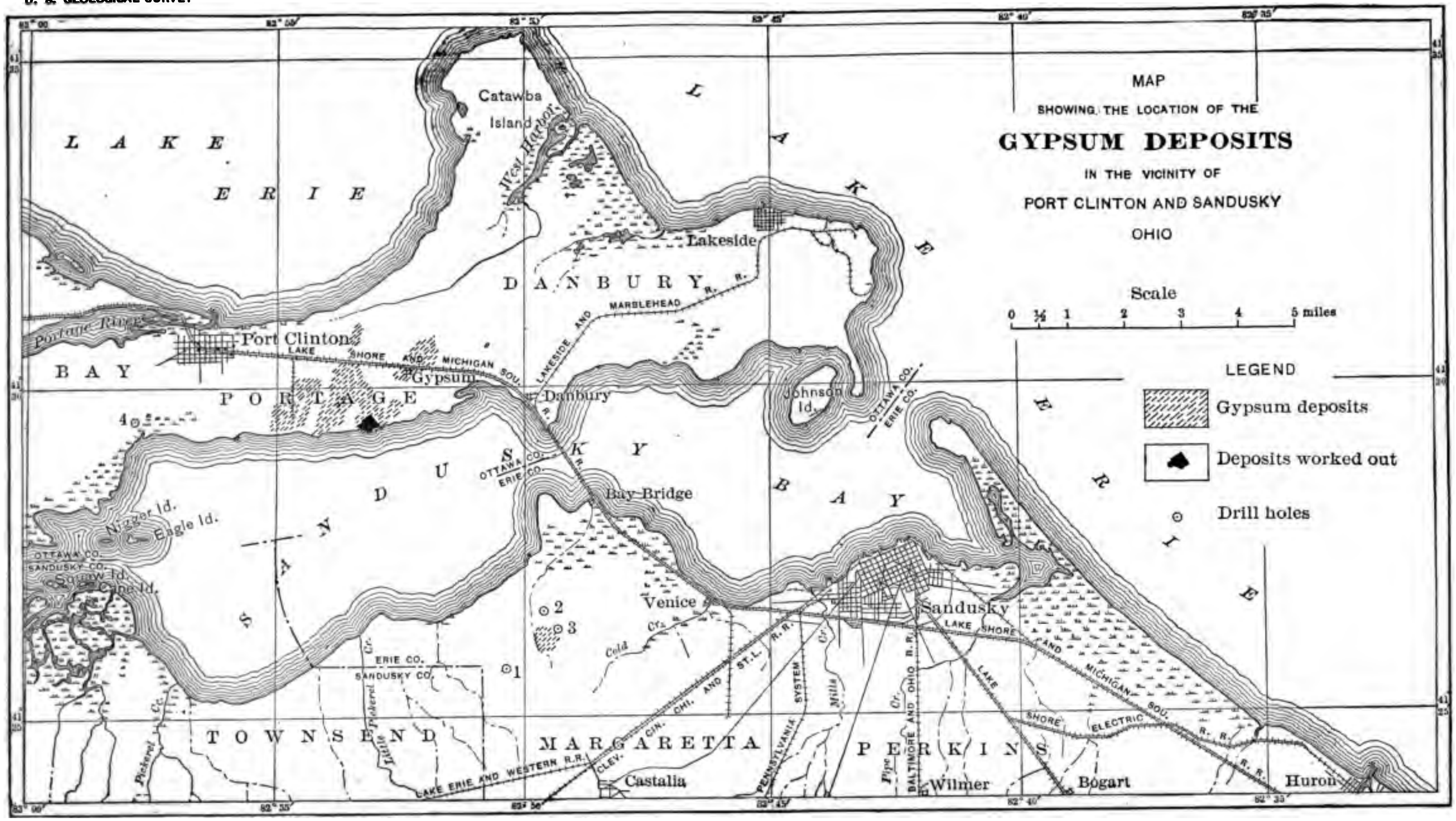
[a] Geol. Survey Ohio, vol. 6, p. 697.


MAP
SHOWING THE LOCATION OF THE
GYPSUM DEPOSITS
IN THE VICINITY OF
PORT CLINTON AND SANDUSKY
OHIO
Scale
0 ½ 1 2 3 4 5 miles
LEGEND
Gypsum deposits
Deposits worked out
Drill holes
LAKE ERIE
LAKE ERIE
SANDUSKY BAY
BAY
Catawba Island
West Harbor
Lakeside
DANBURY
PORTAGE
TOWNSEND
MARGARETTA
PERKINS
Port Clinton
Portage River
Gypsum
Danbury
Johnson Id.
Bay Bridge
Venice
Sandusky
Castalia
Wilmer
Bogart
Huron
Eagle Id.
OTTAWA CO.
ERIE CO.
SANDUSKY CO.
LAKE SHORE AND MICHIGAN SOU. R. R.
LAKESIDE AND MARBLEHEAD R. R.
LAKE ERIE AND WESTERN R.R.
CLEV. CIN. CHI. AND ST. L. R.R.
PENNSYLVANIA SYSTEM
BALTIMORE AND OHIO R.R.
LAKE SHORE ELECTRIC R. R.
Cold Cr.
Mills Cr.
Pipe Cr.
Little Pickerel Cr.
Pickerel Cr.
1
2
3
4

ECONOMIC DEVELOPMENT.

At the present time two calcining plants are in operation in Ohio. One is at Fletcherville, 1½ miles southeast of Port Clinton; the other is three-fourths of a mile south of Gypsum station. It is reported that a third plant is to be erected in the near future by a company owning considerable deposits and having others under lease. The deposit on the south shore of the bay may eventually be developed.

In the beginning of operations the gypsum was won by open quarries. This necessitated the removal of from 15 to 25 feet of overburden, which consisted of earth, clay, and stone. Recently underground mining has been resorted to, the entrances for the most part being from the old workings. Pl. X, *A*, shows the south side of the quarry at Fletcherville, with three entry openings. Pl. X, *B*, shows an entrance on the north side of the same quarry. Two shafts are in operation in the district. In the mines at Gypsum station three beds are worked. At Fletcherville the top bed is absent. The main bed is at present worked and the lower is undeveloped. Inasmuch as the gypsum lies at a low level there is considerable water, so that it is necessary to use pumps in the workings. The water that comes from the mines, as well as that found in most of the deep drill holes, is a potable water, highly impregnated with sulphuretted hydrogen. In prospecting on the south shore of the lake a strong flow of water was encountered, which fills the drill holes nearly to the top. The question has been raised as to whether the water would interfere with the working of the deposits. Inasmuch as the drill records show that in nearly every case the water is not encountered except below the lowest gypsum bed, it is reasonable to conclude that the heavier beds can be worked without unusual inconvenience if care is taken not to penetrate the lower formations.

On the north shore of the bay one of the quarries has been abandoned, because the waters of the lake were let in through a crevice which was found in the workings. An attempt was made to build a dike in the bay and to pump the water out of the quarry, so that the gypsum close to the shore could be obtained. The experiment, however, was not successful.

The gypsum industry in Ohio has increased rapidly in the last few years. The principal portion of the product is used for wall plaster. There are within the State eight companies which are engaged in the manufacture of hard wall plaster. Most of their material is obtained from Ohio. Next in importance is the use of plaster in the manufacture of plate glass. A considerable amount is employed in the making of crayons. Minor amounts are used in making pottery molds, in the manufacture of Portland cement, and as land plaster.

DESCRIPTIONS OF LOCALITIES.

The deposits on the south shore of the bay, north of Castalia, were discovered several years ago in sinking a well. Recently a core drill has been used in prospecting the locality. Eight drill holes have shown an area of about 10 acres of good gypsum having considerable thickness. This lies at what is known as the Alfred Meggit farm. The driller reports the following record:

Drill record at Alfred Meggit farm, near Castalia, Ohio.

	Feet.	Inches.
Earth	30	..
Limestone	7	..
Limestone and gypsum interstratified	6	..
Gypsum	3	6
Limestone and gypsum interstratified	4	..
Gray plaster	9	..
Gypsum	3	10
Limestone	4	..
Gypsum	6	4
Limestone	1	..
Gypsum	3	2
Limestone	6	..
Total	83	10

At a depth of between 75 and 85 feet a heavy flow of water was encountered, which filled the drill hole to within 6 or 8 feet of the top.

A hole drilled for the Castalia Portland Cement Company about 1 mile southeast of the one above described, and on slightly lower ground, gave the following section:

Section near Castalia, Ohio.

	Feet.	Inches.
Earth	46	6
Gray limestone	19	..

Water in large amount came in at the bottom. The approximate location of this drill hole is shown on the accompanying map (Pl. IX), and is numbered 1. A hole drilled in the flat north of the deposit (numbered 2 on the map) gave practically no gypsum. A hole a short distance to the east (numbered 3 on the map) gave but little gypsum. Drill records apparently indicate a local ridge or roll of gypsum, which is believed to lie in a somewhat semicircular area. On the north side of the bay the drill record at locality marked 4 on the map was as follows:

Section on north side of Sandusky Bay, near Port Clinton, Ohio.

	Feet.
Earth	42
Limestone and gray plaster	16

A. VIEW OF SOUTH SIDE OF FLETCHERVILLE GYPSUM QUARRY.

B. VIEW OF NORTH SIDE OF FLETCHERVILLE GYPSUM QUARRY.

The term "gray plaster" in these drill records signifies a mixture of gypsum and limestone, the masses and nodules of gypsum varying from those of small size up to that of a large bowlder. Between Port Clinton and the shore of the bay no workable gypsum has been found.

One and one-half miles southeast of Port Clinton gypsum is found on what is called the Lutzinger farm, where five holes have been drilled. One of the drill records is as follows:[a]

Drill record on Lutzinger farm, near Port Clinton, Ohio.

	Feet.	Inches.
Earth	30	..
Gypsum	..	18
Rock	10	..
Gypsum	4	..
Rock	8	..
Gypsum	3	..
Rock	6	..
Gypsum	4	..
Rock	2	10
Gypsum	5	..

Eight holes have been drilled on what is known as the Charles Hehr farm. The record of one them is as follows:

Drill record on Charles Hehr farm, near Port Clinton, Ohio.

	Feet.	Inches.
Earth	19	..
Rock	..	18
Gypsum	6	2
Rock	3	8
Gypsum	2	7
Rock	2	..

Five holes showing gypsum have been drilled on the Joseph Fletcher place, which is the site of the Fletcherville plant. The record of one of the holes is as follows:

Drill record at Fletcherville plant, near Port Clinton, Ohio.

	Feet.	Inches.
Earth	14	..
Rock	..	18
Gypsum	10	..
Rock	3	..
Gypsum	6	..

Between this place and the Forrester shaft, which is next described, some gypsum was found in a hole near the line of the Smitherbeck farm, but is not considered sufficient to work. It was reported to have a thickness of 3 feet 2 inches.

[a] This and the following sections are taken from the driller's record; in every case the "rock" is probably limestone.

The record of the Forrester shaft on the Smitherbeck farm is as follows:

Drill record at Forrester shaft on Smitherbeck farm, near Port Clinton, Ohio.

	Feet.	Inches.
Earth	17	..
Gypsum (bowlder)	2	..
Rock	..	5
Gypsum	..	10
Rock	2	..
Gypsum	..	7
Rock	3	7
Gypsum	1	8
Rock	2	4
Gray plaster	7	..
Rock	..	4
Gypsum	4	..
Rock	..	10
Gypsum	1	6
Rock	..	10
Gypsum	4	..

The following is a record of the hole on the McDonald farm:

Drill record on McDonald farm, near Port Clinton, Ohio.

	Feet.	Inches.
Earth	14	..
Rock	6	..
Gypsum	..	20
Rock	1	8
Gypsum	6	..
Rock	1	9
Gypsum	2	6
Rock	5	..

On the second farm, known as the Fletcher farm, a drill hole gave the following record:

Drill record on Fletcher farm, near Port Clinton, Ohio.

	Feet.
Earth	17
Rock	8
Gypsum	6
Rock	4
Gypsum	3

To the east the gypsum deposits, according to the information thus far available, are relatively unimportant. There is evidently a continuous ridge of gypsum extending to the northeast, as shown by the records of drill holes on the Payne farm, one of which is as follows:

Drill record on Payne farm, near Port Clinton, Ohio.

	Feet.	Inches.
Earth	28	..
Rock	5	6
Gypsum	1	..
Rock	2	5
Gypsum	4	3
Rock	1	..

A. EXPOSURE AT NORTH END OF MARSH & CO.'S QUARRY.

B. EXPOSURE OF GYPSUM IN OLD QUARRY OF MARSH & CO.

A large amount of gypsum has been taken from the Lockwood farm, near the shore of the bay. The deposits on this place have been nearly worked out. A short distance to the north of it is the quarry and shaft of Marsh & Co. A drill hole just northeast of the of the mill gave the following record:

Drill record near shaft of Marsh & Co., near Port Clinton, Ohio.

	Feet.	Inches.
Earth	18	..
Rock	1	..
Gypsum	6	6
Rock	1	..
Gypsum	5	..
Rock	7	..
Gypsum	4	..
Rock	4	..
Gypsum	5	..
Rock	3	..
Gypsum	2	..
Rock	10	..
Gypsum	3	..
Rock	2	..
Gypsum	3	..
Rock	5	..
Gypsum	10	..
Rock	2	..

The gypsum at the lower levels is somewhat better in character, being clearer and containing some masses which are transparent. Three-fourths of a mile northeast of the last-mentioned place, at Gypsum station, there is a 4-foot bed of gypsum overlain by 60 feet of earth rock. A little north of the station, on the Miller place, there is a bed of gypsum between 3 and 4 feet thick, lying at a depth of 72 feet. The upper and heavier beds apparently were not present at this locality.

The variable thickness of the limestone and gypsum beds is well illustrated by a comparison of the sections above described. It is also clearly shown by two sections given below, which were taken about 225 yards distant from each other. No. 1 is on the north side of the quarry and No. 2 on the south side.

Sections near Gypsum station, Ohio.

	No. 1.		No. 2.	
	Feet.	*Inches.*	*Feet.*	*Inches.*
Soil and clay	18	.....	8	......
Limestone	1	.....	10	...... (shaly)
Gypsum	6	6	2	......
Limestone	1	.....	.....	1 to 6
Gypsum	5	.....	6 to 6	6
Limestone	7	.....	.....	6 to 12
Gypsum	4	.....	3	......

The three benches of gypsum given in section No. 2 are shown in the accompanying illustration (Pl. XI, *B*), which is a view of a small portion of the quarry just west of the mine entrance. Pl. XI, *A*, shows the north end and east side of the same quarry.

It has already been suggested that the gypsum occurs in waves or rolls. These areas correspond to some degree with the surface of the ground, since as a rule only the high ground is found to be productive. However, in some cases the gypsum extends into the low ground. The general trend of the rolls is from northeast to southwest.

Prof. Edward Orton[a] gives the following section:

	Feet.
Drift clays, level of bay, 8 feet below surface	12–14
No. 1. Gray rock carrying land plaster	5
Blue shale	½
No. 2. Bowlder bed carrying gypsum in separate masses, embedded in shaly limestones	5
No. 3. Main plaster bed	7
Gray limestone in thin courses	1
No. 4. Lowest plaster bed, variable	3–5
Mixed limestone and plaster bottom of quarry. Water enters here in quantity.	

The beds are not even and horizontal, but are found in waves or rolls, the summits of which rise 5 to 8 feet above the general level. Sections like the one here given will yield 50,000 tons of plaster to the acre.

The bed marked No. 1 in the section is a mixed deposit of shale and plaster that has hitherto been rejected, but which has recently been found fully available for grinding into a dark-colored land plaster. It has been lost by erosion in much of the territory already worked, and is not commonly counted among the valuable resources of the quarries.

No. 2 is one of the most interesting divisions of the section. Scattered through the calcareous shales there are balls of gypsum, concretionary in form and probably in character, varying in diameter from 6 to 24 inches. For a long while it was thought that they were of inferior value, and they were ground into land-plaster, but recently it has been found that the purest product of the quarries can be derived from these same plaster balls. The gypsum yielded by them when they have been carefully freed from their shaly envelopes, proves to be of the whitest and purest sort, such as is used as terra alba.

GEOLOGIC RELATIONS.

The gypsum deposits of Ohio occur in what is known as the Rondout (Waterlime) formation of the Silurian system, and lie within 150 to 250 feet from the top of it. The rock overlying the gypsum and interstratified with it shows distinctly the lithologic characteristics of this formation. The conditions under which the gypsum was deposited were not favorable to life, and, as might be expected, there is no conclusive evidence as to the age of the beds available from fossils. It is impossible to trace the beds by means of exposures or sections, or to determine their relation to the formations below. However, 10 miles to the east the Onondaga (Corniferous) is recognized, and 26 miles to the west the lower beds of the Rondout waterlime are exposed.

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[a] Geol. Survey Ohio, vol. 6, p. 698.

GYPSUM DEPOSITS IN MICHIGAN.

By G. P. Grimsley.

CHARACTER AND EXTENT.

The gypsum in Michigan is of the massive rock variety and occurs in heavy ledges. It is of high degree of purity. The deposits of economic importance are found in two portions of the State, though there is possibly a third area, as yet undeveloped. The two important areas are Grand Rapids and vicinity, on the western border of the Lower Peninsula, and Alabaster, on the eastern border, on Saginaw Bay. The third locality, where very little is known concerning the value of the deposits, is near St. Ignace, on the Upper Peninsula, and perhaps some of the northern islands of the Beaver Island group, where it would have to be mined.

The mills on the western border of the State are located in the valley of Grand River just below the rapids. The gypsum south of the river is found near Plaster Creek, and its outcrops in this creek have been traced for a distance of a mile from the Grandville road, north to the river. The bottom of the gypsum rock is about 10 feet above the river. North of the river the mines enter the hill at the level of the river plain, but on a downward incline from the level of the ground at the mills, and these mines are locally spoken of as caves.

In the city and northward, beyond the city limits, gypsum is found in wells at varying depths, but it appears to be absent in the wells to the east of the gravel ridges which pass through the town. Gypsum is also found in the deep wells to the west of the city.

The valley of Grand River widens to the south, near Grandville, and the drainage of the south is through Buck Creek. The quarries are located about 1 mile south of the river, and not far above its level, so that water is very troublesome and must be pumped.

The Alabaster quarry is located about three-fourths of a mile from Saginaw Bay, in the eastern part of the State. The bottom of the quarry is 15 or 20 feet above the water level. The gravel beach extends back a few hundred yards, beyond which the land is almost level for a long distance inland, and is more or less marshy. The gypsum is found at a number of places to the south of Alabaster, along the bay, and can be seen extending out from the shore under the water.

ECONOMIC DEVELOPMENT.

In 1838 Dr. Douglass Houghton called public attention to the gypsum deposits in his first State report, and wrote that the gypsum in Kent County "can not fail to prove a subject of much value to the agricultural interests of this and adjoining parts of the State," a prediction which became a reality nearly thirty-five years later. In 1841 the first gypsum mill was erected, and was located on Plaster Creek, near the Grandville road. The mill was equipped with one run of millstones operated by water power, and the plaster was calcined in a 2-barrel caldron kettle. The mill manufactured land plaster mainly, and 10 years after the work was started, they made 60 tons of land plaster daily. In 1849 the first mill north of the river was erected. It is still in operation. A second mill was erected in 1869. At the present time there is one mill in operation south of the river and one idle mill. These are four mills now in use north of the river.

At Grandville two mills were erected in 1872 and a third in 1875. The last is still in operation, while the others are idle.

The Alabaster mill is the only one in the eastern part of the State, and is located at the town of Alabaster in Iosco County. The quarry was opened and mill erected in 1862, and has been in operation almost continually since that time. Much rock is shipped from this quarry to other mills in Chicago and to Ohio.

DESCRIPTIONS OF LOCALITIES.

The original quarry of the Plaster Creek area south of the river, near Grand Rapids, is now filled with water. In the new quarry the gypsum is found in two strata; the upper is 6 feet thick, and is separated by a foot or less of shale from the lower 12-foot ledge. The whole is covered by 12 to 15 feet of shale. The gravel cover is not thick. The upper 6-foot ledge is very irregular in its distribution, and runs out to the east and west within the quarry. On the north side of the quarry both layers of gypsum have disappeared over an area 100 feet wide and extending to the north. The gypsum at the side of this space shows the effects of water in its irregular surface. The main working is on the 12-foot ledge. The lower 2½ feet of this ledge is a red gypsum rock with red cone-in-cone gypsum called by the quarrymen "pencil rock." The bottom rock is a hard blue limestone, called the flint rock.

North of the river the mines have been opened by both drifts and a vertical shaft. The underground workings are on a double-entry system. The gypsum is worked on the drift and bench system, with no undercutting, and the roof gypsum is supported by heavy timbering. A geologic section at these mines shows practically the same series of

gypsum and shales as south of the river, but the upper 6-foot ledge is more constant and is left for the roof of the mine.

In the Grandville quarry the gypsum stratum is 11 feet thick, covered by a foot of dark shale, over which is 20 feet of gravel. The floor of the quarry is a hard limestone 4 feet thick, and below it is a stratum of gypsum 14 feet thick, not worked. A shaft 32 feet deep has now been completed near the mill, and the quarry is to be abandoned.

The Alabaster quarry is the largest gypsum quarry in the State and probably in the United States. The gypsum face is 16 to 22 feet high, covered by 5 to 16 feet of tough bowlder clay, which is removed by steam shovel.

GEOLOGIC RELATIONS.

The interior coal basin of Michigan is almost entirely surrounded by a border of Lower Carboniferous rocks, known as the Grand Rapids formation, which in age probably corresponds to the St. Louis, Chester, and Augusta formations of the Mississippian. This formation is divided in Michigan into the upper Grand Rapids and the lower Grand Rapids. The latter division was called by Winchell the Michigan salt group, but as it is without salt, it has been called by Lane the Michigan group.

The gypsum deposits at Grand Rapids and Alabaster are found in the lower Grand Rapids series. The thickness of this group is stated by Rominger to be 184 feet, and it is underlain by the Napoleon group of shales and sandstones, 123 feet thick, which in turn rest on the sandstones of the lower Marshall group.

The deposits near St. Ignace are in the Salina or Monroe group of the Silurian.

GYPSUM DEPOSITS IN FLORIDA.

By David T. Day.

A deposit of gypsum has been observed about 6 miles west of Panasoffkee, Fla. It occurs in a low-lying area of hummock land, known as Bear Island. Near the marsh which surrounds the so-called island the deposit is covered with cypress trees and, farther in, with rather unusually large palmetto trees and the usual mixture of live oak and magnolia, with occasional low spots where nothing but cypress will grow. In the southern and southwestern portion of this so-called island the gypsum reaches the surface, with no covering whatever except an inch or two of vegetal mold. By striking a hoe into this the gypsum may be dug up in a soft state like clay, but it soon hardens on exposure to dry air. It is greenish while wet and turns white on drying. Where the gypsum is at the surface there are knolls from 10 to 50 feet square and 3 to 6 feet higher than the adjoining land, but the gypsum is found almost everywhere by slight excavation. The deposit is probably gypsite, or secondary gypsum.

Two pits sunk through it have shown it to be 6½ feet thick in one place and 7 feet thick in the other, with the usual light Florida sand underneath. Mixed through it are bowlders of very impure limestone, with occasional hard, flinty ones. As a rule the topography of the country will admit of digging 6 or 8 feet through the gypsum without encountering any considerable amount of water, except in the wet season.

The quality of the gypsum is almost uniform in all the places from which specimens were taken. The quantity is evidently sufficient for a large supply. The mining should be extremely easy except for the considerable work of clearing off the heavy growth of timber, about half of which will be of some value. The only difficulty to be anticipated in the mining is the fact that the lumps of limestone would be encountered at irregular intervals; their character makes it evident that they are residual lumps from limestone which has been dissolved by the action of rain water, as in many other parts of the State. It is probable that the floor of the deposit will frequently be a bed of limestone, very irregular in its surface, so that it will be difficult to dig all the gypsum from it by cheap means. This, however, should be a slight objection only, on account of the apparently large amount of material available, which will probably permit it to be profitably mined, even though a large amount of the bed is left in place.

GYPSUM DEPOSITS IN IOWA.

By Frank A. Wilder.

CHARACTER AND EXTENT.

The gypsum of Iowa, so far as known, is found in a single area of 60 or 70 square miles around Fort Dodge, in Webster County, near the center of the State (see Pl. XII). Within this area it is practically confined to a single bed. It is crossed by Des Moines River, and its extent north and south is about 6 miles, as is well demonstrated by exposures along the river banks. Elsewhere it is heavily covered by glacial drift, but well drillings and prospect holes indicate an extent from east to west of 10 or more miles. The bed is practically horizontal, and varies in thickness from 10 to 25 feet. At least 40 square miles may be regarded as available for economic purposes. Within this area there are spots where the gypsum has been removed by pre-Glacial erosion. For this reason careful prospecting should precede the choosing of a site for mill purposes. If the gypsum area be regarded as only 50 square miles in extent, certainly a moderate estimate, there remains twelve hundred times as much as has been removed since the beginning of the plaster industry in Iowa. The average thickness of the gypsum suitable for plaster is 10 feet, and the yield per acre of a bed of this thickness is 30,000 tons. The deposit seems to lie in a well-defined trough, and instead of thinning out gradually it abruptly gives place to Coal Measure shales. The mantle of drift that covers it everywhere, except along the Des Moines and its tributaries, is from 60 to 80 feet thick.

All of the Iowa gypsum, except the crystals of selenite that are commonly scattered through the Coal Measure shales, is regularly stratified in heavy layers which are rarely less than 6 inches thick, while they attain a maximum thickness of 2 feet.

With the exception of a few thin layers that are scattered through the overlying clay at certain points, one layer is differentiated from another only by the slightest trace of clay, and all go to make up a single compact bed. To the unaided eye the gypsum appears compact and dense. The microscope shows that it consists of a mass of minute crystals in which twinning planes and other crystalline characteristics are well developed. Although the gypsum is nowhere fissile, and breaks without regard to lamination, it is beautifully laminated, the bands, which are usually half an inch thick, being alternately dark-green and white. This characteristic renders it peculiarly fit for hardening, so that it may be used in imitation of marble. Analyses show that the upper layers are composed of remarkably pure calcium

sulphate. The lower layers show 2 per cent of impurities, and are not used in the manufacture of wall plaster.

Where the full thickness of the gypsum bed occurs the miners recognize the following divisions:

Division of gypsum bed in Iowa.

	Feet.
5. Upper rock, suitable for plaster, varying in thickness on account of differences due to loss by pre-Glacial erosion	3–12
4. Six-foot ledge, best of the plaster rock	6
3. Hard ledge, inferior for plaster	4
2. Eighteen-inch ledge, not good for plaster	1½
1. Bottom ledge, not good for plaster	5

Though the gypsum is now well protected by the thick mantle of drift that overlies it, at one time it formed the surface rock and in consequence suffered considerable erosion and solution. Where the overlying drift is removed its surface everywhere appears deeply trenched and worn. At times it is wholly cut out, and records of drillings at points wholly surrounded by gypsum show only gravel.

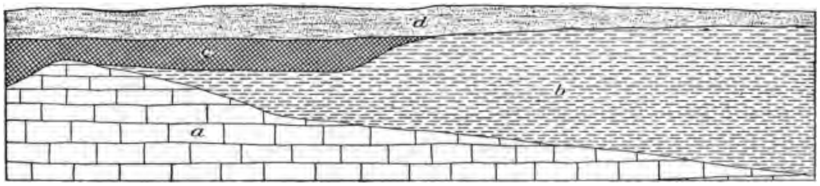

FIG. 5.—Section showing relations of gypsum on Soldier Creek, Iowa. *a*, St. Louis limestone; *b*, Coal Measures; *c*, gypsum; *d*, drift.

Where exposed along ravines the gypsum is decayed to a depth of 3 or 4 inches. Wherever it has been exposed in ledges for a few years it is picturesquely grooved and fluted.

ECONOMIC DEVELOPMENT.

The first gypsum mill in Webster County was erected in 1872 at the head of Twomile Creek, better known as "Gypsum Hollow." It has recently been remodeled. In 1882 the lower mill in Gypsum Hollow was erected, and this was followed in 1885 by the Blandon mill. Shortly after the erection of the Blandon mill, the Duncombe mill was built at the mouth of Twomile Creek. Thus three mills stand to-day on Gypsum Hollow, through which Twomile Creek flows. In 1895 the Cardiff mill began operations. This was the first of the mills built on the prairie. On account of the thickness of the drift, stripping was impossible, and mining by means of a vertical shaft was begun. The success of this mill encouraged the erection of other mills on the prairie, and in 1899 the Crawford mill was completed, and in the spring of 1900 the Mineral City mill made its first shipments. Another mill was erected in August, 1901, in NW. ¼ of sec. 4 of Pleasant Valley Township. Drillings at that point show 40 feet of soil and red shale, and 17 to 22 feet of gypsum. The eight mills in operation at present

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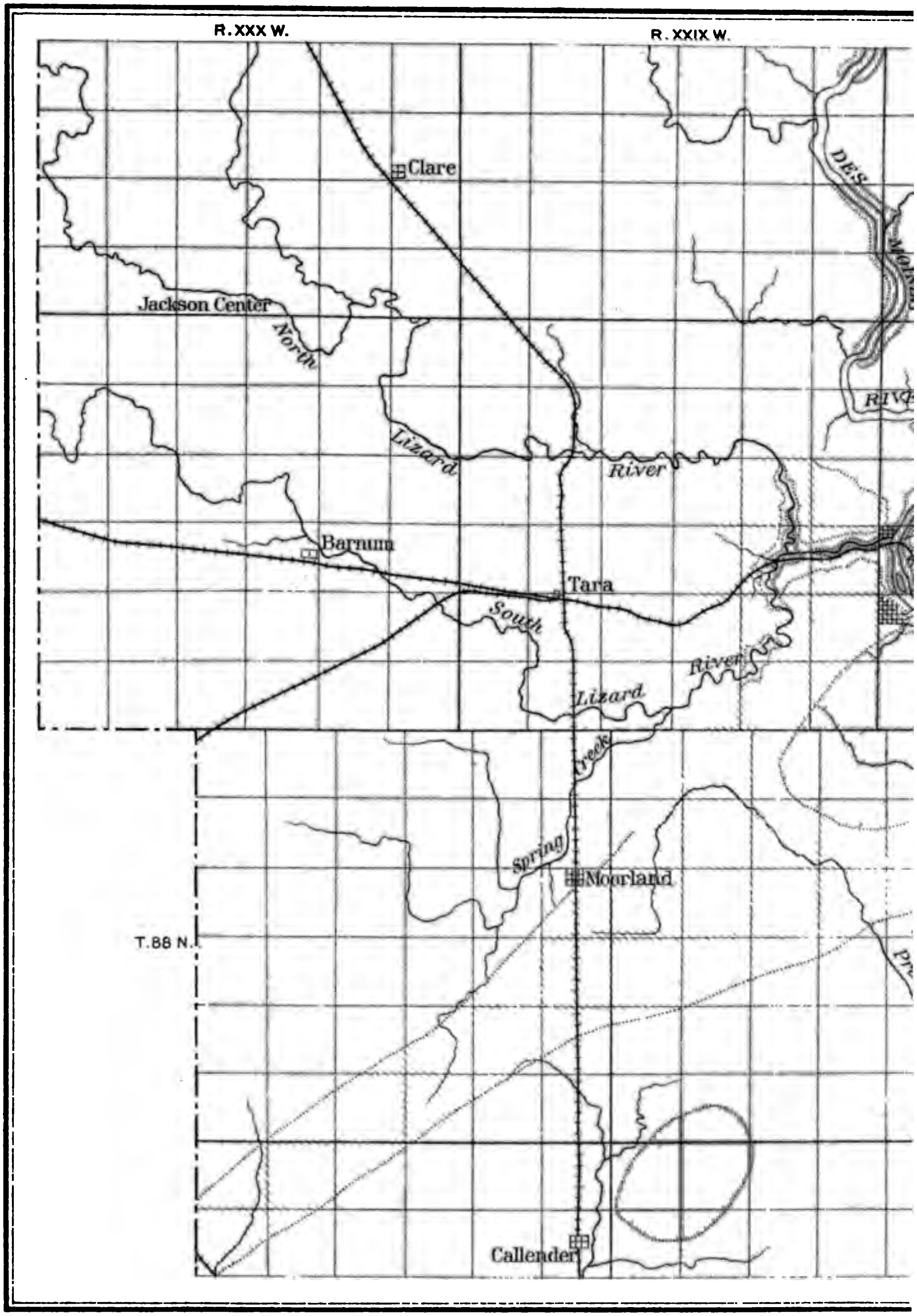


MAP OF PART OF W

SHOWING GYPS

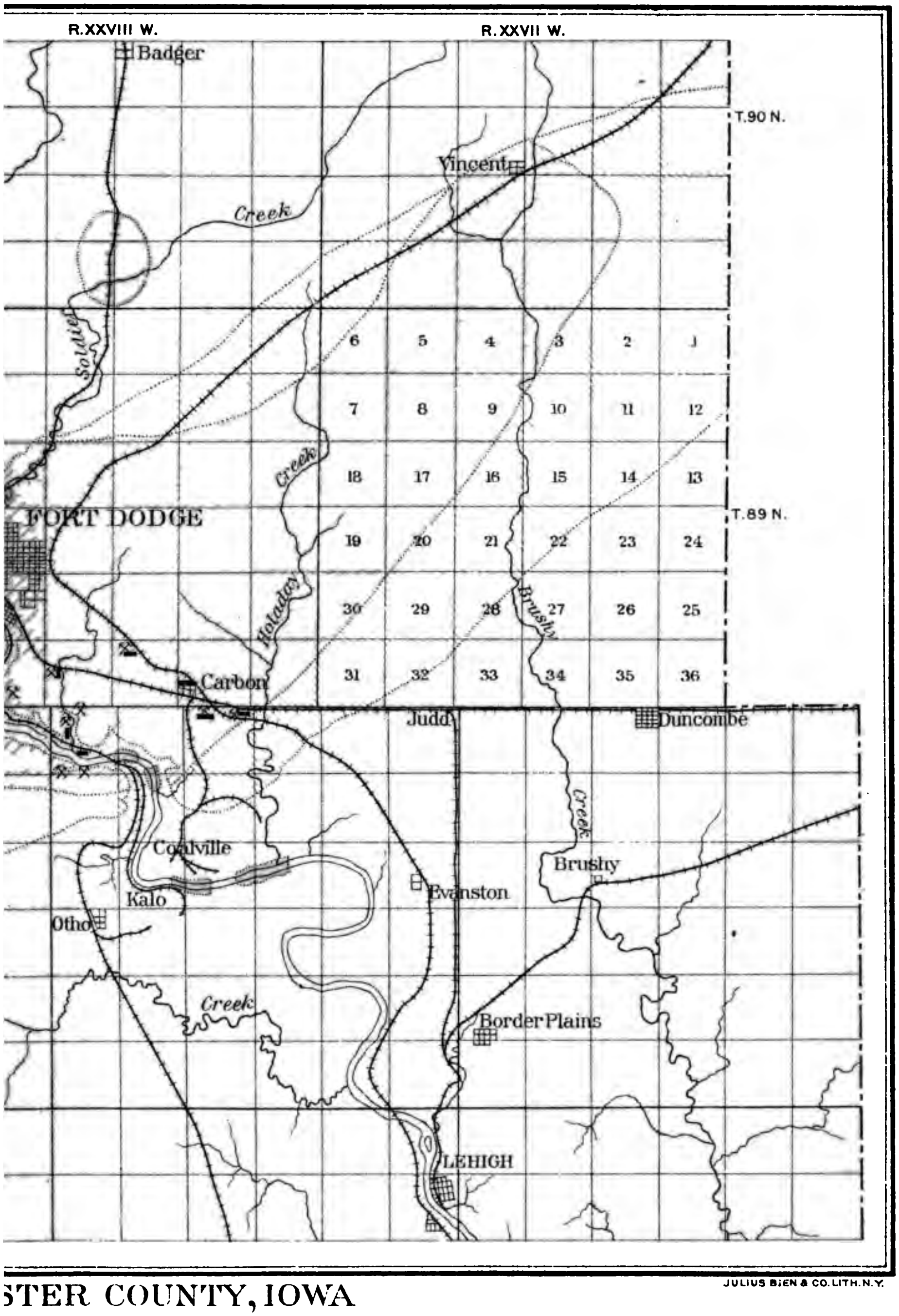
BY F

Permian

Area of Permian in which gypsum is known to occur

Coal Measures

St.Louis



JULIUS BIEN & CO. LITH. N.Y.

STER COUNTY, IOWA

· BEARING AREA

.WILDER

3 4 5 miles

Gypsum mines

Gypsum mills

Glacial drift not shown

have a total capacity of 700 tons of stucco per day of ten hours. The location of all of the mills and mines is shown on the small geologic map of the region immediately about Fort Dodge (Pl. XII).

Most of the calcined gypsum of Iowa is sold as wall plaster. Less than 5 per cent of the product is sold as land plaster. For some years the Iowa Paint Manufacturing Company has operated a mill at Fort Dodge, using finely-ground raw gypsum as a base for paint. The various colors are produced by the admixture of pigments.

GEOLOGIC RELATIONS.

Directly associated with the gypsum, and in perfect conformity with it, are often 20 or 30 feet of red shales and thin sandstone layers, while below and apparently associated with the gypsum is a clay layer 4 feet thick. These relationships, as well as the relation of the gypsum series to the formations above and below, are shown along Des Moines River, and Soldier, Twomile, and Lizard creeks. Away from these streams, wells and prospect holes furnish but imperfect data for determining either the extent of the gypsum area or its stratigraphic relationships.

The gypsum series lies directly on the St. Louis limestone or on the Coal Measure shales (see fig. 5). The surface of the St. Louis limestone was uneven when the Coal Measure shales were laid down on it, and ridges and mounds project many feet into the shales. It is probable that the limestone was at one time wholly covered by the shales, but erosion of the shales before the gypsum was deposited brought the limestone to the surface at a number of points. In this way the varying relationships of the gypsum as exposed on Soldier Creek are to be accounted for. At one point it rests on the limestone and at another only a hundred yards away on Coal Measure shales.

The following section at the mouth of Soldier Creek is typical for the gypsum and associated red shales and sandstones:

Section at mouth of Soldier Creek, Iowa.

	Feet.
Glacial drift	35
Sandstone, soft, friable	5
Red shales, argillaceous, with some thin sand layers	5
Sandstone, buff, friable	2
Shale, gray	2
Shale and thin layer of gypsum	7
Gypsum, massive, exposed	11

The following section in the pit of the Fort Dodge Clay Works shows the relation between the red shales of the gypsum series and the Coal Measures:

Section in pit of Fort Dodge Clay Works.

	Feet.
3. Drift	35
2. Red, sandy shales, with thin layers of sandstone, gypsum series	10
1. Gray Coal-Measure shales, separated from the red shales above by sharp lines of unconformity; along this line there is a layer of gumbo 1 foot thick	30

On the west bank of Des Moines River opposite the Blandon mill the following section is shown:

Section on west bank of Des Moines River.

	Feet.
4. Drift, yellow, unleached, with many limestone pebbles	85
3. Gypsum, badly weathered, exposed	10
2. Limestone containing Coal-Measure fossils (the stone is argillaceous and like the limestone which generally caps the Coal Measures in Webster County)	2
1. Coal-Measure shales, poorly exposed on account of hillside wash	60

The following section is taken from an exposure on Twomile Creek in Gypsum Hollow:

Section on Twomile Creek.

	Feet.
5. Drift	30
4. Red, sandy shale	0-4
3. Gypsum, massive, in places moderately folded, in layers from 6 inches to 2 feet, laminæ averaging three-fourths of an inch, alternating in color, gray and white	20
2. Clay, thickness undetermined	
1. Shale and sandstone (passed through in drilling well at lower mill of the plaster company)	100

A study of the broader relations of the gypsum series of Iowa shows that it lies in a fairly well-defined trough, or basin, stretching across Webster County from northwest to southeast. It rests unconformably on the underlying strata, both of Mississippian or Pennsylvanian age. This unconformity is good ground for believing that if the series belongs to the Paleozoic era, it was formed near its close, during the Permian. The Permian of Kansas, Indian Territory, Oklahoma, and Texas includes immense deposits of gypsum which are associated with clays so highly and characteristically colored as to be known as the Red Beds. Although a careful search has been made for fossils in the Iowa area, neither the gypsum nor the deposits associated with it have yielded any fossils, so that the age can not be determined on paleontologic grounds. This might naturally be expected, since the Red Beds of the Permian farther southwest are nearly barren of fossils. In Kansas, however, there is no unconformity between the Permian and the underlying Coal Measures.

The striking resemblance that the Iowa gypsum series bears to the Permian only 300 miles farther west, makes probable the assumption that the gypsum series of Iowa is an outlier of the Permian of Kansas and Indian Territory. During the long interval before the drift which now protects it was deposited there was abundant opportunity for erosion to remove the Permian from the intervening territory. The gypsum that remains was doubtless protected by heavy beds of red shale, for had it been exposed long it would have yielded to the solvent and erosive action of water.

GYPSUM DEPOSITS IN KANSAS.

By G. P. Grimsley.

CHARACTER AND EXTENT.

The gypsum of Kansas consists of extensive beds of rock gypsum and a number of deposits of secondary gypsum, or gypsite. Some of the rock gypsum is suited to the manufacture of the finer grades of plaster of Paris, and the gypsite is particularly adapted for wall and cement plasters. There is a sufficient quantity of the gypsite now known to permit extensive operations for a number of years. Certain of the deposits, however, have shown signs of exhaustion, and have been abandoned. It is probable that others will be discovered, as there is a demand for further development of the industry. The rock-gypsum beds are so vast in their proportions that only those which are favorably situated with respect to transportation facilities will probably be worked.

The area in which gypsum is found is an irregular belt extending northeast and southwest across the State (Pl. XIII). It is naturally divided into three districts, which, from the important centers of manufacture, may be named the northern or Blue Rapids area, in Marshall County; the central or Gypsum City area, in Dickinson and Saline counties, and the southern or Medicine Lodge area, in Barber and Comanche counties. A number of small areas have been developed between these, connecting more or less closely the three main areas. The gypsum is found at Manhattan and north of that city, though not worked. It is worked at Longford, in the southern part of Clay County, and is found near Manchester, in the northern part of Dickinson County. Gypsum is worked near Burns, and has in past years been worked near Peabody and Furley, and large deposits are known near Tampa. Farther south, in Sumner County, a large mill has been operated at Mulvane, and gypsum has been quarried at Geuda Springs. These different localities show an almost continuous belt of gypsum across the State.

From an examination of a map of west-central United States with the gypsum deposits indicated thereon, it will be seen that if the northeast line of the Kansas deposits is extended it will strike the Fort Dodge area in Iowa, and if it is continued to the southwest it will strike the extensive deposits of Canadian River in Oklahoma and Indian Territory and Texas.

ECONOMIC DEVELOPMENT.

The secondary gypsum deposits were developed first in Kansas, where they were discovered in 1873, near Gypsum City. This first deposit was not worked for plaster until 1889, and was abandoned about 1893. For a number of years the darker color of plasters made from gypsum earth hindered their sale, as the whiter plaster from the rock made a more beautiful wall, and was regarded as stronger. With the construction of the ornamental structures at the World's Fair, in Chicago, this earthy gypsum plaster was found to be adapted to staff work, and large amounts were so used. Soon after this time the plasterers became interested in the plaster, and many have regarded it as better adapted for certain work than the rock plaster.

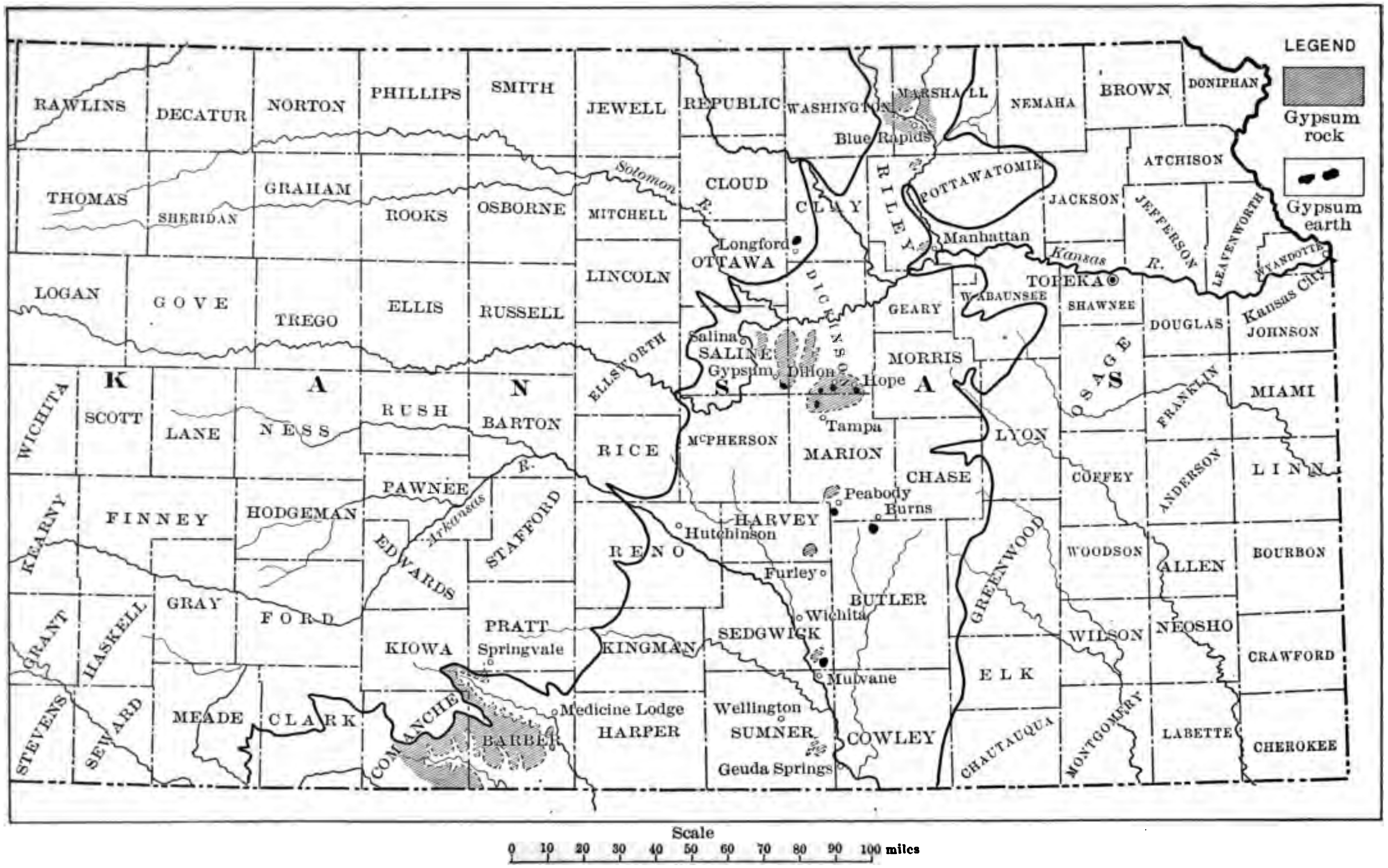
Four of the nine Kansas plaster mills are now using this secondary gypsum in the manufacture of wall plasters. This variety of gypsum is said to require less retarder than rock plaster.

The excellent transportation facilities make Kansas a good area for gypsum plaster manufacture, as there are four main lines of railroads reaching the gypsum fields. The Blue Rapids and central areas are especially well connected by railroads with the cities of Colorado, and with Kansas City and St. Louis. The largest area, near Medicine Lodge, is not reached by any trunk-line railroad, and this fact has hindered its development. There have only been two small mills erected in this field.

DESCRIPTIONS OF LOCALITIES.

The first deposits of gypsum worked within the State of Kansas were in the northern area. The first mill was erected at Blue Rapids in 1872. This mill was operated until 1889, and then abandoned. In 1887 a frame mill of one-kettle capacity was built on the west side of the town, at what is known as the Fowler mine. The entry to the mine is 15 feet above the water level, though the gypsum bed rock is the bed rock of the river, which is 4 feet deep at this place. The entry runs east about 400 feet, and the gypsum dips west toward the river.

The gypsum occurs as a gray mottled rock with saccharoidal texture, breaking with irregular fracture. It is somewhat crystalline, showing fibers and plates. Near the upper part the tendency to crystallization is seen in the dark, irregular plates which characterize that portion of the stratum. The top consists of a layer one-fourth to one and three-fourths inch of white selenite needles forming satin spar. These stand vertical, and they appear to be oriented with the dark plates below. A similar layer of satin spar is found on the lower surface of the gypsum. The rock is traversed by blue clay seams, which contain a small amount of carbonate of lime. These are neither large



MAP SHOWING GYPSUM DEPOSITS AND THE APPROXIMATE LIMITS OF THE PERMIAN IN KANSAS.

nor numerous enough to injure the rock for plaster, and in some parts of the stratum they are absent. On exposure to the air for some time, or when crushed, the rock becomes very soft and snow-white.

In this mine "cutters" or veins occur which contain masses of transparent selenite crystals grown together, varying in size from the very smallest to those several inches in length.

The Great Western mine is located on the side of a bluff 1 mile north of the town of Blue Rapids and about 50 feet above the level of the water in the river. It is $2\frac{1}{4}$ miles southeast of the Fowler mine. The entry runs east of north, and goes into the hill over 400 feet. The section of the mine and hill above, fig. 6, shows a gypsum bed $8\frac{1}{2}$ to 9 feet in thickness.

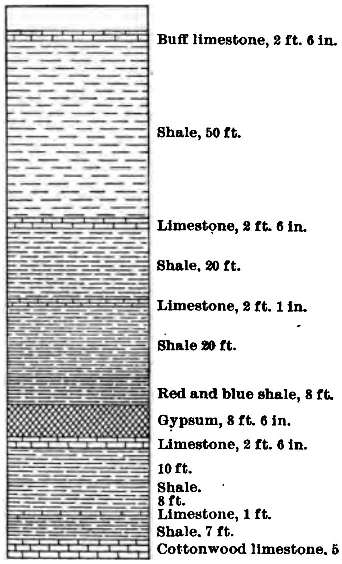


FIG. 6.—Section at Great Western gypsum mine, Blue Rapids, Kans., showing relations of gypsum to Cottonwood limestone.

On the bank of the Little Blue, 2 miles west of Blue Rapids, is located the Winter mine. The rock was formerly obtained by stripping, and a very considerable area was thus worked out; but as the cover became thicker back from the river, it was thought to be more economical to mine by running an entry into the hill. This entry is about 15 feet above the level of the water, and runs east about 1,000 feet into the hill. The double-entry system of mining is used, with rooms 16 feet square. A geologic section at the mine shows a compact limestone floor on which rests 8 to 9 feet of gypsum. This is covered by about 10 feet of red and blue shales, and two limestones of 2 and 3 feet thickness, separated by 11 feet of shales and shaly limestones.

In the northern part of the central or Gypsum City area, 6 miles southwest of Solomon, on the bank of Gypsum Creek, a mine was formerly worked. A section of the hill at the mine, represented in fig. 7, shows 40 feet of shales and gypsum. The mine entrance is 15 feet above the water in the creek, and the stratum worked was 5 feet thick. The shales, with the intercalated gypsum layers, are folded and broken. The folds extend down into the mine, causing the shales of the roof to cut out the gypsum in many places. This fact caused the abandonment of the mine. The dip of the gypsum is north, toward the creek. The lower part of the heavier gypsum layer is very compact, and filled with crystals of yellowish-brown selenite, having the greater length in the direction of the vertical crystal axis. The crys-

tals are laminated by a pronounced pinacoidal cleavage. The larger ones are about seven-eighths of an inch long and half an inch wide, and rock specimens from this portion of the stratum break with a conchoidal fracture. The upper part is white, less compact, contains no such crystals, and pieces break more irregularly.

At Hope, 20 miles southeast of Solomon, there are gypsum deposits which have been in operation since 1887. At first gypsum rock was quarried near the top of the hill, 1½ miles west of the town. The bed is 5 feet thick, and lies 10 feet below a buff, shaly limestone. The gypsum is white and compact in texture, except near the surface, where it is rendered granular and more or less colored as a result of weathering. The satin spar associated with it is of clear white color. In 1894 this quarry was abandoned, and at a point a quarter of a mile west of the quarry a shaft 80 feet in depth was sunk to a lower stratum of gypsum, which is nearly 14 feet thick. The rock is white, though much of it is traversed by wavy dark lines which lie close together, giving an appearance somewhat like granite or gneiss, so that the plaster made from it is called by the company "granite cement plaster." The lower part of the stratum is compact, and contains rounded crystals of selenite, with dark, mottled surfaces. It thus bears a close resemblance to the Solomon gypsum, already described, although the crystals are usually larger, averaging about 2 inches by 1 inch. A study of the levels and character of the rock indicates that the gypsum quarried below Solomon is the same as that in the shaft near Hope.

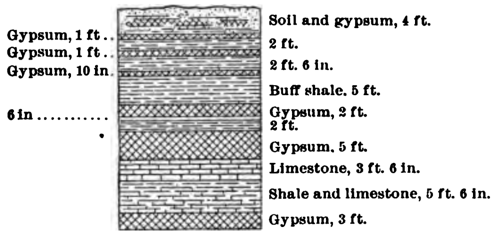


FIG. 7.—Section at Solomon gypsum mine, Kansas.

South of Dillon an 18-foot stratum of gypsum rock is being worked. It is reached by a shaft 78 feet in depth.

Important secondary deposits of gypsum occur at a number of places in the central and southern areas. They supply the greater portion of the plaster manufactured in Kansas. The material is locally called "stucco," "gypsum dirt," "gypsite," and other similar names. It is a granular earth, found in low, swampy ground, dark colored in place, but on drying it assumes a light ash-gray color. It is soft and incoherent, so that it is readily shoveled into cars, and is ready for calcining with less labor and expense than is required in working the solid rock. The first deposit was discovered in the spring of 1873, near Gypsum City. It covers an area of 12 acres, and lies close to the surface, with little or no cover. The maximum thickness is 17 feet, with an average of 8 feet. The appearance of the deposit resembles very much a fine sand bed or loess formation, and there is a tendency to break into

smooth planes or joints. Strong springs break through the deposit on the east side. The top of the gypsum earth is 20 feet above the water in Gypsum Creek, a quarter of a mile to the west. In a well dug on the hill above the deposit, rock gypsum of good quality was struck 30 feet down, or 20 feet below the top of the earth. No trace of gypsum was found in the hills above the gypsum earth.

The gypsite deposit near Dillon, 14 miles east of Gypsum City, is very similar to the one last described, and is at least 40 acres in extent. It lies in swampy ground near a small creek. Its greatest thickness is 18 feet. It is covered to a slight depth with soil. Springs of water occur through this deposit and are very troublesome when the gypsite is worked. Gypsum rock outcrops a quarter of a mile away, at the same level. The gypsum earth was taken out by aid of the plow and scraper, and after drying a few days in the sun was loaded into cars and hauled to the mill, one-half mile north. The mill was taken down a year ago and moved to Acme, Tex., and the deposit is no longer worked.

Another similar deposit is located 3½ miles southwest of Dillon in a low place near a small stream, and here again springs prove troublesome. The cover is 10 feet thick, and the deposit varies from 5 to 8 feet. It is claimed that the deposit extends over 60 acres.

Four miles east of Longford, Clay County, and near a small creek, there is a gypsum-earth deposit which varies from 2 to 10 feet in thickness over an area of about 60 acres. Other gypsum-earth deposits are reported from this same region, and near Manchester.

Seven and one-half miles southwest of Burns, close to Davis Creek, in Butler County, a gypsum-earth deposit is worked. This deposit averages 6 feet in thickness, and is whiter than the material in the other deposits in the State. It is covered by a thin layer of soil varying from 1 inch to 2 feet in thickness. Where Davis Creek cuts through the gypsum the deposit is about 9 feet thick, and has a jointed structure, breaking out in large blocks. Thus far gypsum rock has not been found in the region above this gypsum-earth deposit, nor has it been reported in any of the wells in that vicinity.

Gypsum earth has been worked 2½ miles northeast of Mulvane, just across the Sedgwick County line. The material was 3 to 12 feet thick, and was worked for several years. The deposit showed signs of giving out, so the mill was removed.

This southern gypsum area is the largest in Kansas, and with its continuation in Oklahoma and Texas forms the largest gypsum area in the United States. The rock extends from near the town of Medicine Lodge westward through Barber and Comanche counties, southward into Oklahoma, and passes under the Tertiary gravels to the north.

The gypsum of the Medicine Lodge area is mainly rock gypsum, is

white in color, and in the lower portion of the stratum is very compact. The satin spar which is found throughout the Red Beds below the gypsum is in the form of wavy plates, with perpendicular needles. It is variable in character; some of it is soft and readily crumbles, while other portions are compact and glassy in appearance.

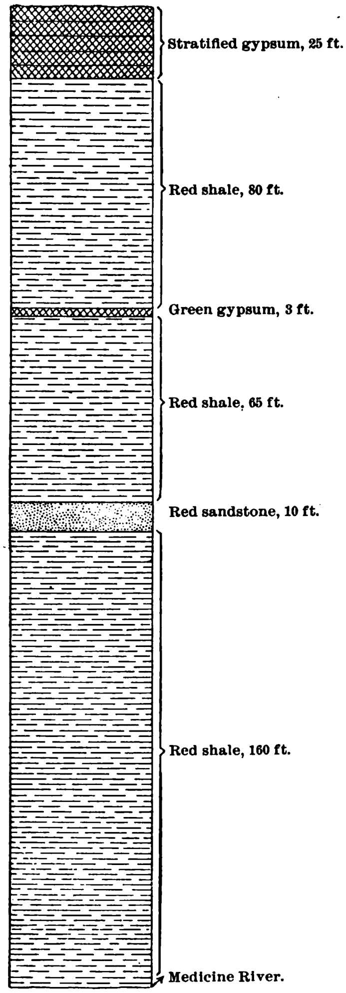


FIG. 8.—Section of Medicine Lodge Hills, 7 miles southwest of Medicine Lodge, Kans.

The gypsum is first seen 6 miles southwest of Medicine Lodge, in an isolated range of hills 3 miles long, separated by a narrow valley from a second hill 1 mile in length. The valleys of East and West Cedar creeks, 2 miles wide, separate these hills from the next series, in which the gypsum plateau is continuous to the west.

In the eastern part of Comanche County, on Cave Creek, a second gypsum layer, 15 feet thick, is found 15 feet above the Medicine Lodge layer. This upper layer was called the Shimer gypsum by Cragin. It appears to be a local deposit.

Looking west from the town of Medicine Lodge one can see in the distance a range of eroded hills with sloping sides and level tops. These hills extend in a north-south direction, and are called the Gypsum Hills. The sides are composed of the red shales and clays of the Red Beds. The cap rock is a ledge of gypsum, which has protected to a considerable extent the underlying soft strata. A section of the hills at Medicine Lodge is shown in fig. 8. The gypsum layer varies from 3 to 20 feet in thickness, depending upon the amount of erosion. The red clays and shales below the gypsum contain an interlacing network of selenite and satin-spar layers of variable thickness. This material has been dissolved out of the solid stratum and carried downward through the agency of circulating water and redeposited.

In the western part of Barber and the eastern part of Comanche counties the solvent effects of water on the gypsum are well shown, for there are found natural bridges and underground watercourses.

GEOLOGIC RELATIONS.

In the northern or Blue Rapids area the gypsum, as is shown by the section, fig. 6, is 30 feet above the Cottonwood limestone, which has been taken by Prosser and others as the dividing line between the Coal Measures and the Permian. This places the northern gypsum in the basal portion of the Permian. The gypsum deposits near Hope, Solomon, and Dillon are somewhat higher stratigraphically and in the division of the Permian known as the Marion. The Medicine Lodge beds are the highest in the series. The gypsum at Geuda Springs occupies an intermediate position between the Medicine Lodge horizon and that which is interbedded with the Permian limestones, and is in the blue shales known as the Wellington shales, which farther south, in Oklahoma, have as their equivalents red shales and sandstone.

GYPSUM DEPOSITS IN OKLAHOMA.

By Charles N. Gould.

CHARACTER AND EXTENT.

Oklahoma occupies a central position in the belt of country which carries extensive gypsum deposits all the way from the northern part of Kansas into central Texas (see Pl. XIV). Within its borders the number and thickness of the beds appear to be greater than to the north and south. The amount of gypsum appears to be inexhaustible. With perhaps two exceptions, each of the western counties contains enough material to supply the United States for an indefinite length of time, and there are in addition considerable deposits in the eastern part of the Territory. For convenience of discussion the gypsum in Oklahoma may be considered as occurring in four regions: (1) The Kay County region; (2) the main line of gypsum hills, extending from Canadian County northwest through Kingfisher, Blaine, Woods, and Woodward counties to the Kansas line; (3) the second gypsum hills, parallel with the main gypsum hills, and from 50 to 70 miles farther southwest, which extend from the Keechi Hills, in southeastern Caddo County, northwestward through Washita, Custer, Dewey, and Day counties; and (4) the Greer County region, occupying the greater part of western Greer County and the extreme southeastern corner of Roger Mills County.

The deposits in Kay County consist of gypsum dirt, or gypsite. In the other three regions rock gypsum predominates, although there are numerous localities where gypsum dirt occurs in workable bodies. The amount of rock gypsum in Oklahoma has been approximately estimated by computing the area and the thickness of the exposed beds and reducing the amount to tons. The quantity in each county is set forth in the following table:

Estimated amount of gypsum in Oklahoma.

	Tons.
Canadian County	50,000,000
Kingfisher County	50,000,000
Blaine County	2,500,000,000
Woods County	14,000,000,000
Woodward County	24,000,000,000
Comanche County	200,000,000
Caddo County	3,000,000,000
Washita County	20,000,000,000
Custer County	6,000,000,000
Dewey County	1,000,000,000
Day County	500,000,000
Roger Mills County	1,000,000,000
Greer County	53,000,000,000
Total	125,300,000,000

MAP SHOWING GYPSUM DEPOSITS IN OKLAHOMA.

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The total of 125,300,000,000 tons, however, fails to convey an idea of the extent of the gypsum resources, because the amount is so enormous. In the above estimate the gypsum in Kay County, and other gypsum-earth deposits, are not included, because they occur in local and irregular areas.

ECONOMIC DEVELOPMENT.

Notwithstanding the fact that gypsum is widely distributed in Oklahoma, the amount manufactured in the Territory is relatively small. This is due in large part to the fact that it is a newly settled country, in which railroads have but recently been constructed. Moreover, the cost of transportation is important, even where railroad facilities are good. The gypsum industry has had an extensive development in Kansas, to the north, and the Texas deposits have been worked to some extent. Oklahoma has had to compete with these neighboring States. Another matter scarcely less important than that of transportation is the one of fuel, but, fortunately, the Indian Territory coal fields are relatively near at hand.

In addition to the matter of transportation of the finished product, the handling of the raw material and the delivery of it at the mills has to be considered if operations are carried on economically. There are now a number of locations suitable for gypsum mills, and the building of branch railways promises access to more of the deposits.

At the present time there are but four mills in operation. One is located at Peckham, in Kay County, one at Okarche, in Canadian County, and one at Watonga and one at Ferguson, in Blaine County. The mill at Peckham is situated 1½ miles southeast of the town, and was erected in the summer of 1899. The raw material is gypsite, or gypsum dirt, which is hauled to the mill in wagons. The mill at Okarche has been in operation for a number of years. In the beginning of operations raw material was obtained near at hand, but, as is frequently the case, the deposits which were first worked have been exhausted, so that it is necessary to haul the gypsum earth a distance of nearly 2 miles. The mill at Watonga is 3 miles distant from the gypsum deposits, but the mill and quarry are both located on a railroad, which affords transportation facilities. The deposit which is worked at Ferguson is on the head of Salt Creek, 4 miles west of the town, and consists of rock gypsum exposed in heavy ledges. It is quarried and transported by a gravity tram a distance of 500 feet to the mill.

There has recently been some development of the deposits at Cement, in the Keechi Hills, in Caddo County. Gypsum dirt is shipped from this place to the mill at Marlow, Ind. T., the deposits at Marlow having been exhausted. It is probable that the industry will receive further extension in the near future.

A point which is of interest in connection with the working of the Oklahoma gypsum is the fact that springs of good water can often be found in the vicinity of the deposits. These springs are located in the sand hills or surficial deposits, and the water from them is either piped to the mills or raised into reservoirs. The supply is usually adequate for steam and domestic use.

DESCRIPTION OF LOCALITIES.

Kay County.—The gypsum deposits in Kay County are found in the valleys of Duck, Bois d'Arc, Bitter, and other creeks that flow southward into the South Fork in the vicinity of Newkirk and Blackwell. They do not appear to be very extensive, although they have furnished sufficient material for the operation of the plant at Peckham. The region is slightly rolling, and the valleys of the creeks are shallow. The rocks in this region consist of gray and bluish clays and shales, with a few ledges of soft, impure limestone. The deposits have about the same general relations as the gypsite deposits in southern Kansas, and, like them, are of secondary origin. Gypsum is not uncommon in the rocks of this region, although no extensive beds are known. The gypsum dirt has probably been deposited by surface evaporation of waters which contained it in solution. The deposits which have thus far been worked are in places 10 feet in thickness and cover several acres. It is not known whether other workable deposits of the same relative position as those in Kay County will be found farther south in the eastern part of Oklahoma. There are many localities, however, at which farmers dig small amounts of gypsum dirt and manufacture it into plaster for their own use.

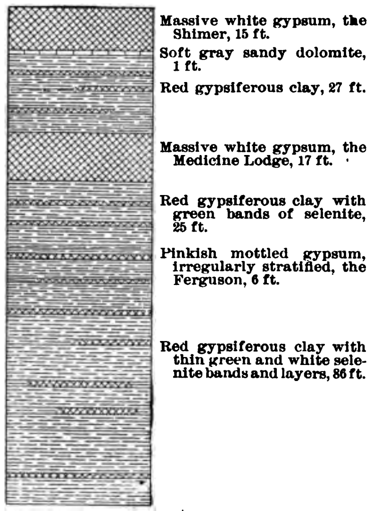

FIG. 9.—Section near the gypsum mill, Ferguson, Blaine County, Okla.

Main line of gypsum hills.—The first ledges of rock gypsum encountered in crossing Oklahoma from east to west are along the main line of gypsum hills, which extend uninterruptedly from the vicinity of Elreno, Okla., northwestward beyond Medicine Lodge, Kans., the best development being along the south side of Cimarron River, in Woods and Woodward counties. These hills contain two, and sometimes three, ledges of massive white rock gypsum, interstratified with beds of red clay shale. The clay weathers more rapidly than the gypsum, and the protecting cap of gypsum rock gives rise to an escarp-

ment. The numerous isolated hills which lie to the east of the escarpment are remnants of it which have been cut off by erosion. In addition to the gypsum there are some thin ledges of dolomite which act in a manner similar to the gypsum in producing the characteristic topographic forms of this region. The disintegration of the shales below the gypsum cap causes huge blocks to break off and fall down the slopes into the canyons, so that quantities of these bowlders are strewn on the surface.

Viewed from the east, the gypsum hills appear as a wall crowned with a white ledge. The sky line, however, is not continuous, since numerous breaks occur where the gypsum has been eroded. Where the escarpment is broken and the country is dissected by streams there are flat-topped buttes or mesas. Not infrequently bold points stand out at short distances east of the main hills. Some of the more conspicuous of these outliers have received distinct names, such as Glass Mountain (see Pl. XV, *A*), Wildcat Buttes, Mount Heman, and Cedar Hill. The main range of hills has likewise received local designations, such as Stony Hills, in Blaine County, east of Watonga, and Chautauqua Mountains, for the hills in Blaine and Woods counties. The name Marcy Range has been proposed for the entire series of hills, but it is doubtful whether it will ever replace the cowboy name of "Gyp Hills." The height of the escarpment varies from 50 to 250 feet, according to its proximity to the main streams of the region.

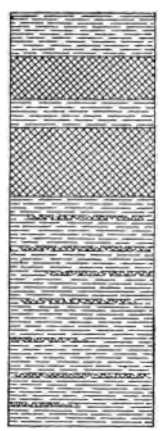

FIG. 10.—Section southeast of salt plain in Woodward County, Okla.

The three conspicuous gypsum beds in this line of hills have been given names. The lower is the Ferguson gypsum. It extends from Canadian County northward into Woods County, where it disappears. The bed above it is known as the Medicine Lodge gypsum. It extends uninterruptedly from Canadian County to the north of Medicine Lodge, Kans., for which place it was named. The third gypsum ledge is known as the Shimer gypsum. It has practically the same extent as the Medicine Lodge, but is not quite so thick.

Figs. 9 and 10 show the relations of these beds at two localities in the line of hills.

Second gypsum hills.—To the west of the first gypsum hills, and at a higher level geologically, there is a line of outcrop of gypsum beds which is here described as the "second gypsum hills." These hills differ in being less well defined as topographic features. This is largely due to the fact that the gypsum beds are not uniform in character and do not continue for long distances. Sections made at various places

show little agreement in the alternation of gypsum, clay, and sandstone beds. At some places nearly the entire interval is occupied by gypsum, while at others it is absent or is represented by thin and irregular deposits. The gypsum appears usually in bluffs and canyon walls, or capping mounds or the summits of rounded hills. The width of the area in which gypsum is found varies from a few miles to as many as 30 miles in some places. The southernmost portion of this line of deposits is found in the northern part of Comanche County, south of the Keechi Hills, which are situated principally in Caddo County. The ledges outcrop in rounded knobs in the prairie region. In Caddo County some of them attain a thickness of 50 feet, but usually they are not over 15 feet thick. There are extensive deposits of gypsum dirt at this locality, which have already been developed to a limited extent.

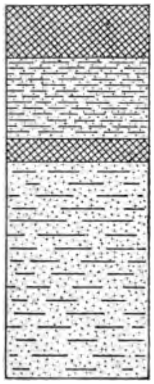

FIG. 11.—Section of a butte 5 miles southeast of Cloud Chief, Okla.

Northwest of the Keechi Hills, in Caddo County, there is a smaller area in which the ledges of gypsum form the cap of a line of bluffs which continue for a considerable distance along the south side of Washita River.

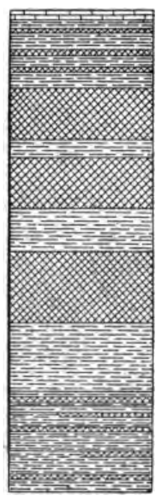

FIG. 12.—Section of a bluff 3 miles south of Carter, Roger Mills County, Okla.

In the western border of Caddo County the gypsum again appears, from which place it extends northwestward into Washita County,

A. GLASS MOUNTAIN, WOODS COUNTY, OKLA., CAPPED WITH MASSIVE GYPSUM.

B. ESCARPMENT CAPPED WITH GYPSUM LEDGES, RED RIVER VALLEY, GREER COUNTY, OKLA.

where this line of hills may be said to culminate. The stratification is here very irregular. The section shown in fig. 11, taken 5 miles southeast of Cloud Chief, shows that the gypsum is in heavy beds. This section can not, however, be considered typical, since a short distance away a bed 50 feet in thickness was found, and from a well near Seger a bed 115 feet in thickness was reported, besides several thinner beds.

In Custer County the gypsum is widely distributed, certain of the beds being more than 60 feet in thickness, and there are often several ledges 10 or more feet in thickness found in the same hill.

In Dewey County there is practically but one stratum which is persistent. It occurs in the buttes and bluffs in the central and western part of the county and varies from 2 to 5 feet in thickness. It continues along the valley of the South Canadian, into the eastern portion of Day County.

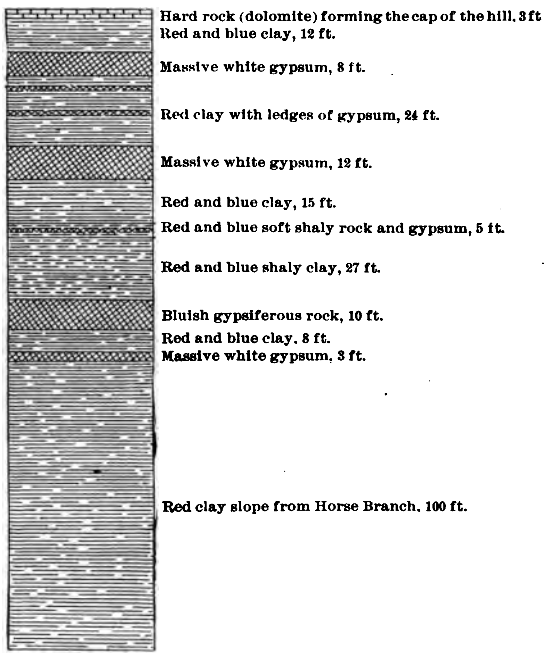

FIG. 13.—Section of a bluff on Salt Fork, 10 miles south of Mangum, Greer County, Okla.

Greer County region.—The gypsum found in Greer County is believed to be the equivalent of the beds described as occurring in the second gypsum hills. Thus far it has been impossible, however, to definitely trace the connection satisfactorily, and a comparison of the sections is an unsatisfactory method of correlation, because of the erratic nature of the beds in the second gypsum hills. In Greer County the gypsum ledges are very regular, the individual beds being persistent for long distances. In this respect they are similar in appearance to those of the first line of gypsum hills. They are more numerous, however, since there are five which are well defined. The three upper ones are the thickest and most conspicuous. The lower two are not more than 4 feet in thickness, and because of their position near the foot of the bluffs, are often concealed. The gypsum beds have been named as follows, from the base of the section up: Chaney, Kiser, Haystack, Cedartop, and Collingsworth.

The Chaney gypsum is well exposed along the south side of Elm Creek, from Mangum, in Greer County, northwest of the Texas line. It extends into Roger Mills County, but is much changed in character, frequently being simply a gypsiferous band in the red clay.

The Kiser gypsum varies considerably in local sections. Usually it is from 1 to 3 feet in thickness, and is best exposed in the western portion of Greer County.

The Haystack gypsum is the heaviest of the ledges in this locality, varying in thickness from 18 to 25 feet. It is conspicuous along the bluffs on North Fork and Elm Fork.

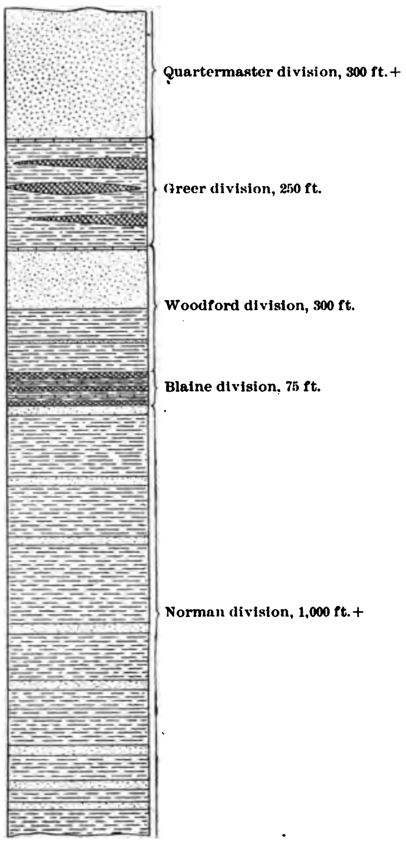

FIG. 14.—General section of the formations of Oklahoma.

The Cedartop bed is massive and from 18 to 20 feet in thickness. It is very regular in occurrence, and is found capping buttes and bluffs, especially along the North Fork, Haystack, and the Elm Fork.

The Collingsworth gypsum is not materially different from the two beds previously described. It varies from 18 to 20 feet in thickness, but inasmuch as it is the upper bed it does not always occur in the section, erosion having carried it away.

The occurrence of the gypsum ledges has given rise to broken topography where the streams have cut their canyons. Over considerable areas in the southern part of the county, however, erosion has not exposed the beds, and the country is accordingly rather level. At such places the presence of the gypsum beneath is occasionally revealed by sink holes, which have resulted from its solution.

GEOLOGIC RELATIONS.

The gypsum deposits in Oklahoma are of Permian age. This is determined by the occurrence of vertebrate fossils in the Norman division, near Hardin and Orlando, at horizons lower than the gypsum, and invertebrate fossils which have been found higher in the section at White Horse Springs. The stratigraphy of the region is difficult to determine, except where there are outcrops of persistent gypsum ledges and of some thin beds of dolomite. The other forma-

tions are essentially shales and sandstones, which have no distinctive lithologic characters and which are difficult to identify in the outcrops. In passing across the country from west to east certain changes in the character of the rocks are readily observed, but in establishing the section the recognizable horizons are, as has already been stated, the dolomites and gypsum. A general section is given in the accompanying figure (fig. 14), and the divisions proposed are indicated in it. It will readily be seen that there are two groups of gypsum beds—those in the Blaine division, found in the first line of gypsum hills, and the beds in the Greer division, which occur in the second line of gypsum hills and the Greer County area. The lower beds extend northward into Kansas, past Medicine Lodge, to a point where they disappear under the overlapping Tertiary. Southward, in Texas, there are extensive deposits, which may be the equivalent of the upper group, or possibly in that region the gypsum is at a higher horizon.

GYPSUM DEPOSITS IN TEXAS.

By Benjamin F. Hill.

CHARACTER AND EXTENT.

The occurrence in Texas of gypsum deposits of great extent has long been known through the reports of early exploring parties. Captain Marcy, in the report of his expedition along Red River in 1852, mentions the gypsum beds encountered in his journey and comments upon them as follows:

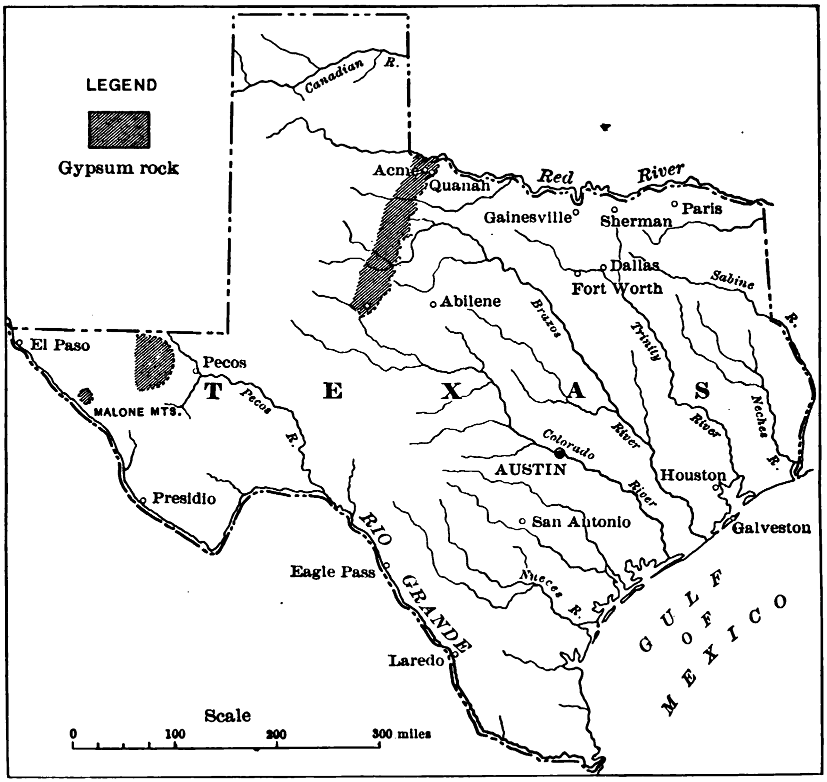

FIG. 15.—Map of Texas showing location of areas containing principal deposits of rock gypsum.

I have traced the gypsum from the Canadian River in a southwest direction to near the Rio Grande, New Mexico. It is about 50 miles wide upon the Canadian, and is embraced between the ninety-ninth and one-hundredth meridians west longitude. Whenever I have met the gypsum I have observed all the varieties from the common form to pure selenite. I regard the gypsum belt as a very prominent and

striking feature of the geology of the country. From its uniformity and extent I do not think there is a more perfect and beautiful formation of the kind known. I have myself traced it about 350 miles, and it probably extends much farther.

While the whole of the deposit described by Captain Marcy is not in Texas, and it is now known that the formation is not continuous to the Rio Grande, the deposits are a portion of an interrupted belt which in Texas extends from Red River to the Colorado, and is found again to the west of the Pecos near the New Mexico line.

In the year 1855 the War Department sent out another expedition under the command of Capt. John Pope. Dr. George H. Shumard performed the duties of both surgeon and geologist. His observations on the gypsum deposits of the region between the Pecos River and the Guadaloupe Mountains were published many years later in Geology of Western Texas (Austin, 1886).

In the reports of the geological survey of Texas from 1889 to 1892 there are many observations on the gypsum deposits, especially in the reports by A. F. Cummins. Quotations from his writings and the reports of other members of the survey are given later in this article. The gypsum deposits of Texas have never been adequately treated, and can not be until more detailed field work has been done. The information here presented is from the observations of the writer and the published reports above cited.

The class of deposits which has attracted most attention is the rock gypsum. The areas in which it occurs are shown in the accompanying map of Texas. Thus far no effort has been made to discover deposits of gypsite or gypsum earth. They no doubt occur associated with the rock gypsum at some localities and will be sought for as the industry in Texas develops. A number of geologic formations contain more or less gypsum occurring as individual crystals or concretions. These can not be considered of commercial importance, but because they contain conspicuous amounts at certain localities mention is made of some of them in this report.

ECONOMIC DEVELOPMENT.

There are only two plants for the manufacture of gypsum products in Texas. They are at Acme, near Quanah, on the line of the Fort Worth and Denver City Railway, at the north border of the State. It would seem at first thought that with such enormous deposits other plants would have been established, but the matter of transportation is of so much importance and the position of the deposits with respect to railway lines is not favorable to their successful exploitation. No doubt with the building of additional railways the industry will be established at other points. The line of the Orient Railroad passes through the gypsum belt in the northern part of the State, and when completed will undoubtedly make this resource more available.

and the outcrops are extensive and are favorable for working. It suffers, however, the disadvantage of being distant from market. The absence of sufficient water supply at this place is another serious drawback to its successful exploitation.

Mr. Joseph A. Taff, in his paper describing this locality, says:[a]

The Malone bed is so named because of the great development of gypsum it includes which occurs in the Malone Mountains. * * * The main gypsum field extends from the center of the mountain to the northwest end. * * * The lowest rock exposed of the Malone Mountain horizon is a band of pale-yellow flaggy limestone. Above this limestone occurs the first horizon of white, friable, granular gypsum, having a thickness of 45 feet. Succeeding this gypsum there is 175 feet of massive blue granular limestone. * * * Above this limestone comes a second horizon of gypsum of a thickness of 110 feet. It is the same, lithologically, as the first horizon, a stratified, nearly pure, friable, granular gypsum. It contains comparatively little earthy matter. * * * On the east side of the southeast end of Malone Mountain there is a development of gypsum with a surface area of about 40 acres. * * *

The clays and marls of the Cretaceous formation are frequently gypsiferous, though no deposits of economic importance have been found. Some of the occurrences of this nature are mentioned here since the content of gypsum is important in its relation to the soils derived from the beds. The Arietina or Del Rio clay contains normally large quantities of iron pyrite. Where it has been subjected to the process of weathering the oxidation of the pyrite has set free the sulphuric acid that it contains, and this in turn has combined with the lime in the clay to form gypsum. Crystals of selenite thus formed are often conspicuous in the outcrops. In the marls and clays of the Upper Cretaceous in the Trans-Pecos region, especially in Brewster County, are extensive beds containing selenite. In the Lower Cretaceous limestones, especially the Washita, in the neighborhood of the Terlingua mining district, extensive caves have been formed. Often the caves have subsequently been filled with gypsum of a variety of forms, including massive gypsum, selenite, and satin spar.

In that portion of Texas lying to the east of Brazos River there are numerous localities where the presence of gypsum has been noted. The geologic formations are of Tertiary and Quaternary age.

R. A. F. Penrose, jr., and William Kennedy, in their reports on this region, note the presence of gypsum, sometimes in considerable quantities, in the clays. In the Wills Point bed in particular, in Brazos County, gypsum, chiefly in the form of selenite, occurs in crystals which are sometimes 6 inches long and have attracted considerable attention, although they are of no commercial importance in view of the vast deposits which the State contains.

[a] Second Ann. Rept. Texas Geol. Survey, p. 72.

GEOLOGIC RELATIONS.

The gypsum deposits lying along the eastern foot of the Staked Plains and to the west of Pecos River occur in what are usually called the Red Beds of Texas. The deposits were probably formed continuously, although their outcrop is interrupted from Colorado River to the Pecos by the overlapping of later rocks. They have been referred to the Permian by Mr. Cummins, and have usually been considered as belonging to this age by other writers. The deposits in the Malone Mountains were considered to be of Cretaceous age by Mr. Taff, but the geology of the region is not clear. Mr. Stanton, who has subsequently studied these rocks, refers them to the Jurassic on paleontologic evidence. The age of the beds containing disseminated gypsum has been mentioned in the foregoing discussion of them.

GYPSUM DEPOSITS IN MONTANA.

By Walter Harvey Weed.

CHARACTER AND EXTENT.

Gypsum deposits are widely distributed throughout the eastern flanks of the Rocky Mountain region of Montana, the beds embracing an extent of a great many miles. In general the gypsum occurs interbedded in a series of red and green shales with limestones containing Lower Carboniferous fossils. These beds vary from a few inches to 6 or more feet in thickness, and the gypsum is often pure and free from foreign materials. The deposits so far developed are near the railroads in Carbon and Cascade counties, Montana. The rocks have been flexed by the mountain uplifts, and lie either at steep angles on the mountain slopes or in gentle dips at a distance of a mile or more away from them. The best development of the gypsum formation occurs near Kibbey, Cascade County, but the series of beds may be traced from Missouri River eastward along the flanks of the Big Belt Mountains to Riceville on the Neihart Branch of the Great Northern Railway; thence eastward to the town of Kibbey, and thence around the flanks of the Little Belt Mountains in a nearly continuous exposure to the vicinity of Castle Mountain. Southward from that locality the same horizon can be traced by its red shales, but the gypsum does not occur, so far as known, in sufficient purity or thickness to promise commercial importance. Traced eastward along the flanks of the Rocky Mountains from the vicinity of Livingston to Carbon County, the same red series contains gypsum at various intervals along the outcrop, but it is not until Carbon County is reached that the gypsum is known to occur in sufficient quantity to be of economic importance. This series of beds then extends southward into the Bighorn Basin and can be traced into the mountains of Wyoming.

Besides the geologic horizon just mentioned, gypsum occurs in abundance in Cretaceous beds, which are found through the eastern part of the State, but as a rule this gypsum is so disseminated through the shales that it can not be regarded as of any commercial importance. In rare instances it forms small veins which might be workable. Very commonly it impregnates the waters, both of streams and springs, making them unfit for use. At Hunters Hot Springs, on the north bank of Yellowstone River, about 20 miles east of Livingston,

the hot waters are now depositing gypsum and the old hot spring fissures are filled by a mass of gypsum and stilbite. Up to the present time these deposits, although of considerable extent, have not been utilized.

ECONOMIC DEVELOPMENT.

The gypsum deposits of Montana have been exploited at two localities, one in Cascade County near the towns of Kibbey and Armington, and the other in Carbon County near the town of Bridger. At Kibbey gypsum was mined and manufactured into plaster during the years 1898 and 1899, but in 1900 the plant was burned and has not been rebuilt. A company is now operating at Bridger.

GEOLOGIC RELATIONS.

The beds in Cascade County are unquestionably of Lower Carboniferous age. They lie directly above the heavy, massive, white Carboniferous limestones, and are interbedded with shales and limestones carrying an abundance of Lower Carboniferous fossils of Spergen Hill types. They are immediately overlain by Jurassic limestones, carrying typical fossils, and these in turn by a beach conglomerate which marks the uplift at the close of the Jurassic period. The Carbon County beds have not been critically studied. Their geologic relations, however, are believed to be the same as those in Cascade County.

GYPSUM DEPOSITS IN SOUTH DAKOTA.

By N. H. Darton.

CHARACTER AND EXTENT.

In the Black Hills uplift there is brought to the surface an elliptical outcrop of the Red Beds which give rise to the Red Valley surrounding the high ridges and plateaus of the central portion of the Black Hills. The area is about 100 miles long by 50 miles wide, and the outcrop zone has an average width of 3 miles, except in a few districts where the rocks dip steeply, where it is much narrower. The Red Beds have been designated the Spearfish formation, and while they have usually been regarded as of Triassic age, there is evidence that they may represent the Permian. The formation consists mainly of red sandy shales, with included beds of gypsum at various horizons, some of which are continuous for long distances while others are of local occurrence. The thickness of the deposits varies greatly, but in some districts over 30 feet of pure white gypsum occur, and nearly throughout the outcrop of the formation it contains deposits of sufficient thickness and extent as to have commercial value.

The gypsum is a prominent feature about Hot Springs. Here the principal beds occur about 60 feet above the base of the formation and have a thickness of 33½ feet, exclusive of the 10-foot parting of shale between them, but this thickness diminishes somewhat northward and rapidly southward. The following section is exposed on Cold Brook, a short distance west of Hot Springs:

Section on Cold Brook, South Dakota.

	Feet.
Red shale and thin beds of gypsum	5
Gypsum	15
Red shale with thin beds of gypsum	10
Gypsum	4½
Red clay	1
Gypsum	14
Red clay	2
Gypsum with clay partings	5
Red shale with gypsum veins	10
Gypsum	3
Red clay with gypsum veins and nodules	7
Irregular breccia of gypsum	2
Red clay with gypsum veins	13
Red clay with a thin gypsum bed	3
Banded red and white gypsum	4

In the region north of Edgemont the principal bed of gypsum lies about 80 feet above the base of the Spearfish formation, and is continuous for many miles, with a thickness of 25 feet in most places. It

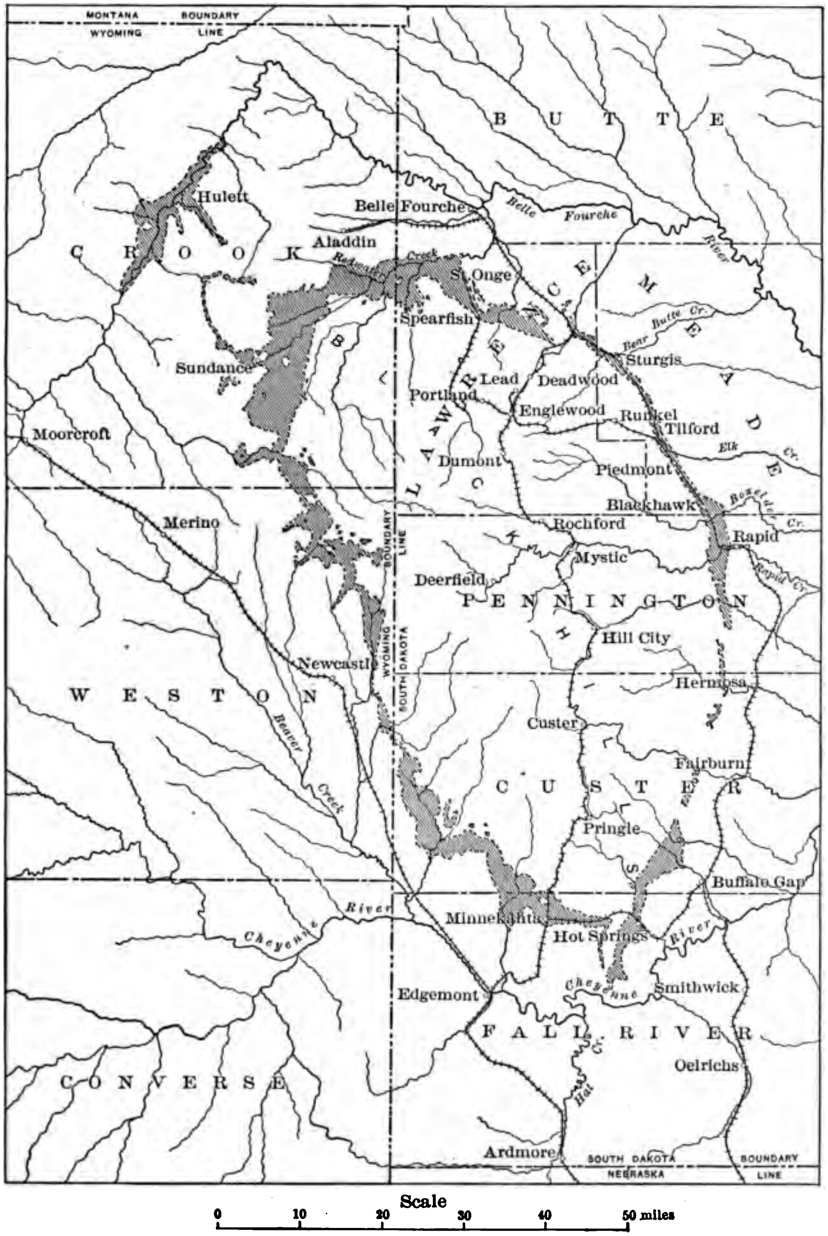

FIG. 16.—Map showing gypsum-bearing formations in the Black Hills of South Dakota and northeastern Wyoming.

is exposed extensively about Cascade Springs and in the Red Valley east and west of Minnekahta station. The following analysis of a

typical gypsum from near Cascade Springs was made by Mr. Steiger in the laboratory of the United States Geological Survey.

Analysis of gypsum from near Cascade Springs, South Dakota.

	Per cent.
Lime (CaO)	32.44
Magnesia (MgO)	.33
Alumina (Al_2O_3)	.12
Silica (SiO_2)	.10
Sulphuric anhydride (SO_3)	45.45
Carbon dioxide (CO_2)	.85
Water (H_2O)	20.80
Total	100.09

East of Newcastle there are thick beds of gypsum in the lower portion of the Spearfish formation and a thick deposit at its top, which extends over an area of considerable size. The lower beds have a thickness of 40 feet at some localities and the upper bed is 30 feet thick. A view of this upper bed, capping Red Butte, northeast of Cambria, is shown in Pl. XVI, *A*. About Sundance, and in the northern portion of the Black Hills, there is a continuous deposit of gypsum about 80 feet above the base of the formation, which extends around the northwestern portion of the hills and thence southward for many miles. About Rapid the gypsum beds vary considerably in thickness, but 10 feet is the average. Portions of the Red Valley along the eastern side of the Black Hills are filled with thick deposits of White River formation which cover the Spearfish formation, but in exposures which are seen at intervals, the usual occurrence of gypsum is exhibited.

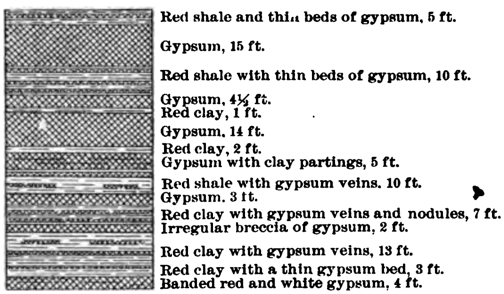

FIG. 17.—Section on Cold Brook three-fourths mile northwest of Hot Springs, South Dakota.

ECONOMIC DEVELOPMENT.

Owing to remoteness from market the gypsum deposits of the Black Hills have not been utilized to any great extent. A plaster mill at Hot Springs has been operated at times, and its very satisfactory product has found ready market, but the expense of long shipment has greatly diminished the profits. Plaster of Paris has also been produced to a moderate extent at Sturgis, especially for local use in Deadwood, Lead, and the other settlements of the northern Black Hills.

A. BUTTE OF RED BEDS CAPPED WITH GYPSUM EAST-NORTHEAST OF CAMBRIA, WYO.

B. BLUFF SHOWING GYPSUM BED 1 MILE NORTHWEST OF HOT SPRINGS, S. DAK.

GYPSUM DEPOSITS IN WYOMING.

By Wilbur C. Knight.

CHARACTER AND EXTENT.

Although gypsum is scattered throughout a vertical range of more than 20,000 feet of sedimentary rocks in Wyoming, the deposits of economic importance are wholly confined to the Red Beds, which are largely made up of red sandstones and shales. This formation, which is one of the most conspicuous in the Rocky Mountain region, outcrops about the base of most of the mountain ranges, or is exposed as the core of small or secondary folds, where erosion has been sufficient to remove the overburden. In all there are about 1,500 miles of the gypsum-bearing formation exposed, and throughout this great linear extent it is the rule to find valuable beds varying from 5 to 20 feet in thickness, and not an uncommon occurrence to find them from 30 to 50 feet thick. All of the gypsum that has thus far been tested is of excellent quality and can be utilized for the manufacture of any of the gypsum products. The beds are usually well located for economic development. In color the gypsum varies from snow-white to pink and gray, but always burns to a snow-white.

Besides the rock gypsum there are secondary surficial deposits of impure gypsum, or gypsite, which occur in depressions below. It is only in recent years that deposits of this kind have attracted any attention, but now it appears that they will be more eagerly sought for than the rock gypsum. Little prospecting for gypsite has been done, but there is every reason to believe that Wyoming will furnish a large amount of this material. Deposits of this nature were first opened in the vicinity of Laramie several years ago, and there are numerous places where beds have been discovered along the base of the Laramie Mountains. Many other localities are favorable for the occurrence of secondary gypsum, and in time no doubt these beds will be reported from nearly every gypsum-yielding locality in the State.

ECONOMIC DEVELOPMENT.

Gypsum was first developed in Wyoming twelve or fifteen years ago, at Red Butte station, on the Union Pacific Railroad, about 9 or 10 miles south of Laramie. A small plant for the manufacture of plaster of Paris and retarded plaster was erected, and this has since been in constant operation. This place was especially favorable for

launching the industry in Wyoming, since at that time it was the only one where the known gypsum-bearing beds were crossed by a railroad. The mill is located near the quarry. A slight amount of surface material has to be removed. Below this there is a pure, almost white, deposit which is worked to a depth of from 8 to 10 feet. This, however, does not represent the entire thickness of the gypsum. In several other places beds have been opened, but owing to the lack of transportation it has been impossible to exploit them commercially. At Dayton, 16 miles west of Sheridan, a quarry has been opened, and also at Alcova; but these are too far from the railroads at present to warrant the erection of plants, except such as will supply the local demand.

Just south of the town of Laramie a very large bed of secondary gypsum was discovered about eight years ago. A Kansas company purchased the ground and erected a large plant. Until last year the plant manufactured but a small per cent of the possible output. The plant was then absorbed by the Acme Company, and is now running full time. The product is shipped as far east as Chicago and westward to the Pacific coast.

The deposit at Laramie is covered with about a foot of soil, which is removed by means of plows and scrapers. Below the overburden there is 9 feet of gypsite without extraneous matter. It is plowed, taken up in wheeled scrapers, and hauled to the storehouse of the mill. The material as delivered by the scrapers is so pulverulent that it is cooked without being ground.

The gypsum beds in Wyoming are so numerous and of such extent and purity that with proper facilities for transportation the industry will become an enormous one in the future, and will be limited only by the demands for the output.

DESCRIPTIONS OF LOCALITIES.

Laramie Mountains.—Along the western slopes of the Laramie Mountains gypsum beds have been traced, by occasional outcrops, from the Colorado line northward for a distance of over 50 miles, and thence northwest 25 miles, to a point beyond Sheep Creek, where they disappear beneath the Tertiary formation. Near the Colorado line there are exposures of high-grade gypsum 50 feet in thickness, lying almost horizontally. To the north the beds thin out a little, but in no place have they been found too thin to work. All along this range the beds dip only a few degrees to the west or the southwest. On the eastern slope of the Laramie Mountains conditions are very different. From the Colorado line northward the Mesozoic and Paleozoic rocks are all tilted to the east at high angles, and were at one time all covered with Tertiary sediment as far north as Platte River. The excavation of the valleys has, however, uncovered here and there small

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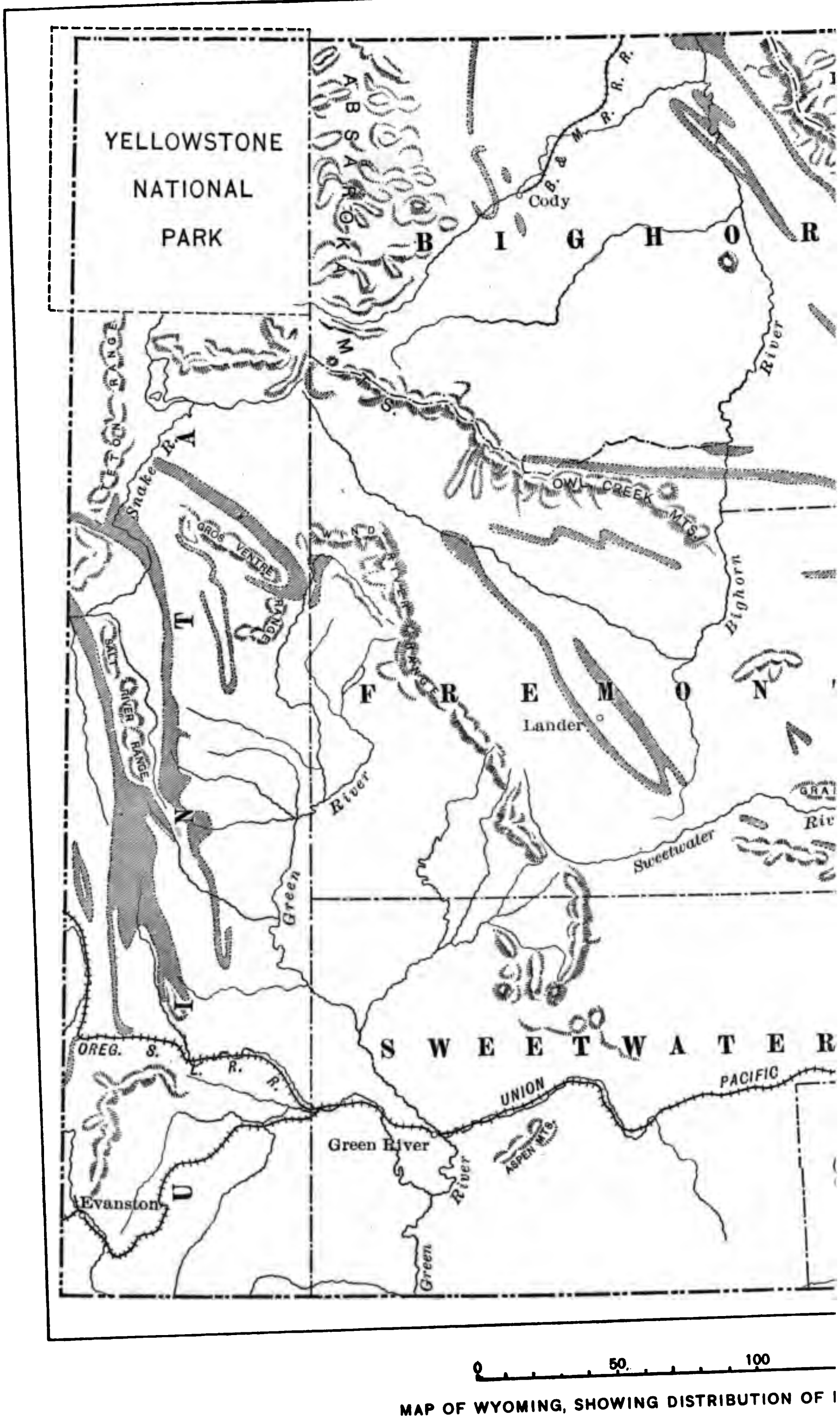
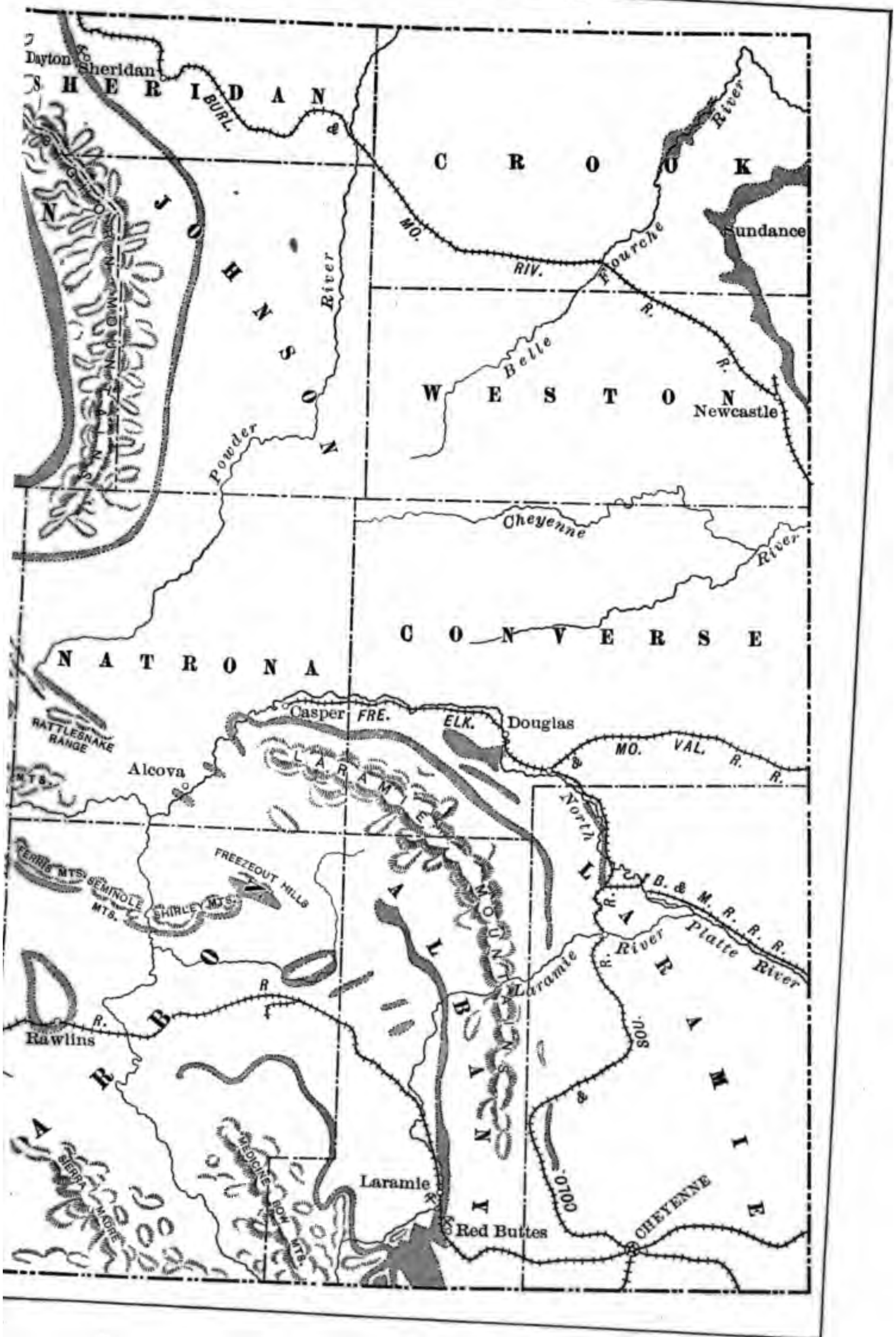


MAP OF WYOMING, SHOWING DISTRIBUTION OF



200
300 MILES

WHICH ARE GYPSUM-BEARING AT MANY LOCALITIES.

areas which show a little gypsum, but nothing of commercial importance has been reported. From North Platte River in the vicinity of Cottonwood Creek to the northwest, and thence to the west to a point 10 miles west of Casper, there are extensive deposits near the foot of the mountains. In fact the gypsum beds encircle the northwestern termination of the Laramie Mountains and extend a few miles to the southeast along the south side, to where the beds are covered with Tertiary rocks. This exposure is in reality the continuation of the beds on

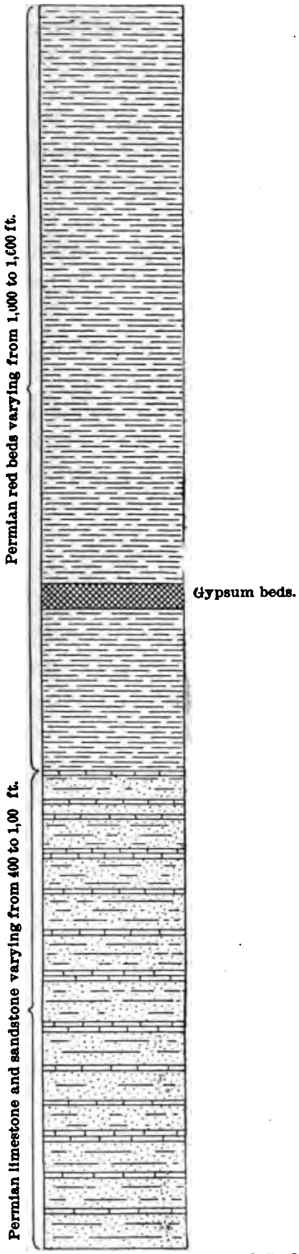


FIG. 18.—General section of Red Beds in southeastern Wyoming, showing usual position of gypsum.

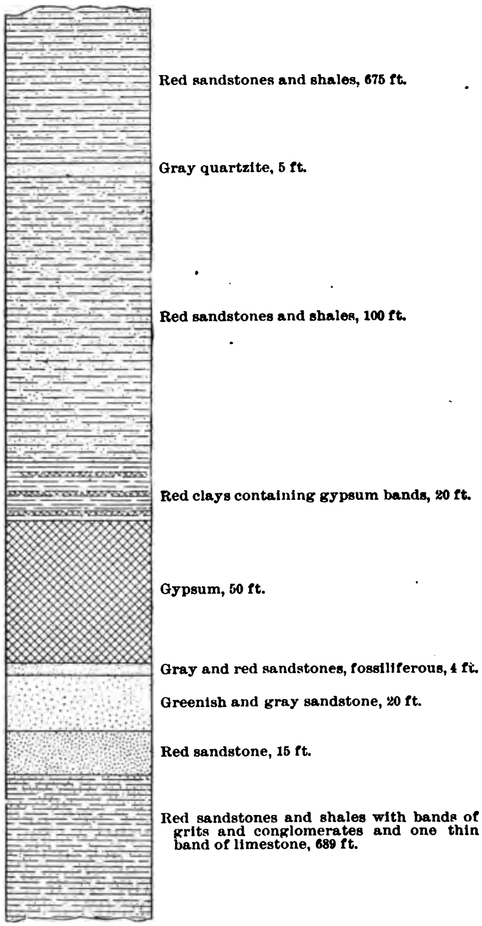


FIG. 19.—Section showing the relations of gypsum in the section south of Laramie, Wyo.

Sheep Creek, which for a distance of 45 miles are obscured by more recent formations. Along the north side of the mountains the beds

are of good thickness, but are as a rule steeply inclined. There is also a secondary fold just south of the town of Douglas that extends for 15 or 20 miles. Along it there are deposits of gypsum that have not been prospected. West of the Laramie Mountains, in the midst of the Laramie Plains, there are four anticlinal folds varying in length from 15 to 20 miles, all of which have exposures of gypsum-bearing rocks on their flanks, and two of these contain large areas of beds that are in rather close proximity to the Union Pacific Railroad.

Medicine Bow Mountains.—About Elk Mountain, the northern termination of the Medicine Bow Range, there are extensive beds of gypsum which are exposed, but along the eastern and western flanks the gypsum-bearing formations are nearly or quite obscured by débris from the higher portions of the mountains or by Tertiary rocks.

Rawlins uplift.—The Red Beds encircle the Rawlins uplift, but for many miles they are covered with sand and soil. Along the eastern slope of the arch the beds dip gently to the east, and at a point 14 miles north of Rawlins the gypsum has been discovered. Along the western slope the beds are highly inclined, and in several gulches good gypsum has been found. Where the railroad crosses this uplift the Red Beds are entirely covered with soil to a considerable depth. Thus far the thickness of the gypsum beds has not been determined.

Freezeout Hills.—The eastern termination of this uplift is about 15 miles north of Medicine Bow, a station on the Union Pacific Railroad in Carbon County. This is a broad anticlinal arch having a length of about 15 miles, and striking nearly east and west. The dip to the north and south is less than 10°, and there are not less than 20 miles of very thick gypsum beds surrounding this uplift.

Shirley Mountains.—This range, which is just west of the Freezeout Hills, is not over 8 or 10 miles in length. Its trend is northwest, and along the southwestern base there are several places where gypsum has been discovered, but nothing is known of its importance. On the north side of the range the Red Beds are not exposed.

Seminole Mountains.—There is a narrow synclinal valley between the Shirley Mountains and the eastern termination of the Seminole, which is composed mostly of Red Beds. They outcrop around that portion of the Seminole Mountains lying east of North Platte River, and extend along the southern border from Platte River westward for a distance of about 10 miles. On the north side of the eastern termination of the mountains the gypsum rocks are entirely obscured by late Tertiary beds. Along this range there are numerous exposures of beds of considerable thickness, but no work has been done to develop them.

Ferris Mountains.—Along the southern base of this range there are gypsum beds exposed where the gulches and canyons have cut across

the formation, but nothing definite is known of the importance of the beds. This range being a fault block, there are no exposures along the northern slopes. Northwest of the Ferris Mountains there are two other mountain-like masses that are imperfectly known, the farthest being called Green Mountain. Gypsum has been found near both of them, but there is no reliable information concerning the characters and thickness of the beds.

Rattlesnake Mountains.—This is a fault range about 60 miles west of Casper, having a general northwest-southeast course. Along the northeastern base the gypsum-bearing formation extends upward of 20 miles, and dips 25° to 30° NE. The beds are very thick, but have not been carefully studied.

Connant Creek.—Forty miles west of the Rattlesnake Mountains there is an anticlinal fold which extends out from beneath the high Tertiary bluff of the Rattlesnake Mountains westward to Beaver Creek. About the termination of this fold beds of gypsum of sufficient thickness to make them of commercial importance outcrop for several miles.

Grand Canyon of the Platte.—Just below this canyon there is a broad valley that has been carved out of the Tertiary rocks. The removal of the Tertiary has exposed two rather extensive areas of Red Beds. The first is at the mouth of the canyon, at which place the gypsum beds are well developed and have a linear extent of not less than 5 or 6 miles. Below the canyon about 3 or 4 miles, and at the town of Alcova, the Red Beds have been brought to the surface by means of a fault, in an area similar to the one just described. The gypsum at this place has been prospected, and very valuable beds are open and awaiting transportation facilities.

Bighorn Mountains.—This range is practically surrounded with gypsum-bearing beds. Along the northern and eastern base the formations are nearly vertical. Along the center of the uplift opposite Buffalo, and for miles on either side, the upturned edges of the Paleozoic and Mesozoic rocks have been covered with a large amount of débris from the mountains. From the northern end of the range to the southeast, nearly to Bighorn, the beds are well exposed and are of the usual thickness and quality. About 10 or 15 miles south of Buffalo the gypsum beds also appear on the surface, and can be traced with but few interruptions until the Tertiary beds are reached southeast of Lost Cabin. On the western slopes the beds are fully as extensive. They dip much more gently than on the eastern slope, and accordingly have more conspicuous outcrop. These beds are nearly continuous from the north end of the range to Thermopolis, and all of the gypsum bands noted have proved thick enough to warrant working. At present the railroad nearest to these beds is the Burlington, and it will probably be a number of years before the deposits will be developed, although the gypsum is of a superior quality.

Owl Creek Mountains.—This range is in reality the western continuation of the Bighorn system, which finally abuts against the Shoshone Mountains. This mountain chain is a rather narrow fold, having a core of Paleozoic rocks, with gypsum beds outcropping upon either side.

Absaroka Mountains.—These mountains are largely made up of volcanic breccia, which forms a covering several thousand feet deep over sedimentary rocks that had been previously tilted. In consequence no gypsum-bearing beds of importance outcrop except in localities where erosion has removed the covering or where the Red Beds were not concealed by the breccias. Most of the gypsum-bearing rocks of this range occur between the Montana line and Cedar Mountain, which is a few miles west of Cody. Nothing of importance has been found out about this region further than that the Red Beds contain gypsum.

Prior Mountains.—The Prior Mountains are largely in Montana, but there is a prominent spur extending southeastward into Wyoming along which the gypsum-bearing formation has been traced as far as the mouth of Grey Bull River, but this probably is not the southeastern limit. There is also a secondary fold between the Prior Mountains and the Bighorn Range, along which there are Red Beds outcropping. All this region is very rich in gypsum, and it is exposed for many miles. It resembles in quality that found in other parts of the State.

Wind River Mountains.—From Miners Delight westward along the foot of the Wind River Mountains, and thence northward nearly to the big bend in Green River, the Red Beds are nearly all obscured by Tertiary rocks, glacial débris, or materials that have been transported by the streams. From the head of Red Canyon, near Miners Delight, to the northwest, along the eastern slope, these beds are continuous for a distance of nearly 100 miles, being only now and then obscured. All along the range where observations have been made there are thick beds of gypsum that dip moderately to the northeast. Parallel to this range, and only a few miles northeast, there is the Shoshone anticline, and along it for a distance of nearly 40 miles gypsum beds are exposed. No attempt has been made to prospect or develop the very thick beds that are known along this great mountain chain.

Gros Ventre Mountains.—Red Beds containing heavy ledges of gypsum are known at many places about this range. The country has been included in the forest reserves, and owing to the lack of transportation it will be many years before there will be any value placed upon the gypsum, although it is of excellent grade and occurs in very thick beds.

Salt Creek Range.—This area may be considered as including all of the territory between the Oregon Short Line Railroad and the Gros

Ventre Mountains. Within it are several north-south folds, along which there are extensive exposures of Red Beds which not only contain gypsum, but also salt, as farther south in the State of Utah. Very little is known concerning the deposits of this portion of Uinta County, except that they are plentiful.

Black Hills.—There is a broad belt of Red Beds encircling the western base of the Black Hills in which gypsum is abundant. These have been discussed by Mr. Darton in connection with the South Dakota deposits.

GEOLOGIC RELATIONS.

As previously stated, the deposits in the State of economic importance are confined to the Red Beds, which have for years been called Triassic. Mr. Darton in describing the Red Beds of the Black Hills region has called the gypsum-bearing portion the Spearfish formation and referred it to the Triassic(?). The Red Beds are a very conspicuous feature in Wyoming geology. They vary in thickness from 1,000 to 1,600 feet, and are composed largely of red shales and red sandstones, which are frequently cross-bedded. Above these rocks the Jurassic series is found, except in places where it has been removed by erosion. In the lower part of the section there is some variation, owing to the fact that the basal portion of the Red Beds in the southern portion of Albany County is equivalent to the limestones and sandstones farther north. In a few localities the Red Beds rest upon the Archean, but as a rule they are conformable upon limestones or a series of alternating limestones and sandstones. These limestones and sandstones have been referred to both the Permian and the Upper Carboniferous. Thus far the paleontologic evidence has been entirely insufficient to place them with any certainty in either. From investigations carried on in the Laramie Mountains it is quite reasonable to believe that the sedimentary rocks directly below the Red Beds will be classed as Permian, and that all of the Red Beds of southeastern Wyoming will also be referred to this series. Recently a fauna has been discovered in the midst of the Red Beds near the Colorado-Wyoming line which places the lower half of the Red Beds of that region unquestionably in the Carboniferous, and there is no reason for placing the upper division in any other system. The rocks of the southeastern portion of Wyoming should, accordingly, no longer be referred to the Triassic. The sections in the western part of the State resemble to a marked degree those made in the eastern, and it is quite probable that the Red Beds there also will prove to be Paleozoic, and perhaps Permian. From what is known at the present time it is believed that the gypsum-bearing beds of Wyoming will prove to be Permian.

GYPSUM DEPOSITS IN COLORADO.

By Arthur Lakes.

CHARACTER AND EXTENT.

The gypsum which is worked in Colorado consists of massive beds which outcrop at intervals from the northern to the southern border of the State, along the eastern foothills of the Rocky Mountains. In addition, there are a number of localities where deposits of considerable importance have been noted. They may be of economic value, but thus far there has been no necessity of exploiting them. There are a few small deposits and certain local occurrences of gypsum which are of interest because of their relation to ore deposits. Some of the shale formations are gypsiferous to a marked degree, so that the water derived from them contains a notable amount of gypsum. When the shale is manufactured into bricks, the gypsum they contain gives them a spotted appearance. The amount of gypsum in the State is far in excess of any prospective demand. The deposits already developed reach a thickness of 30 feet in places, and some of them are of very satisfactory quality. The deposits that are favorably situated with respect to transportation facilities and that are composed of rock of high grade are the only ones which can be expected to become of commercial importance.

ECONOMIC DEVELOPMENT.

Gypsum has been worked extensively near Loveland; beds have also been opened on Bear Creek, near Morrison, and 8 miles to the southeast, on Deer Creek. Quarries have been developed near Perry Park and in the Garden of the Gods, near Colorado City, and in the vicinity of Canyon there are beds which have been utilized to some extent. During the last few years the industry has been confined principally to Loveland, Perry Park, Colorado City, and Canyon, and has shown considerable variation in activity.

DESCRIPTIONS OF LOCALITIES.

But few of the localities in the State have been especially studied with respect to the occurrence of gypsum beds. The one to which the writer has devoted the most attention is at Loveland. It is situated at the eastern foothills of the Rocky Mountains, where the strata have

been folded. The formations have dips varying according to their positions on the arches and anticlines. In the vicinity of the quarry at Loveland erosion has removed the rocks so as to form an amphitheater-like basin, and the exposed edges of the strata circle around a granite spur. The bed of gypsum lies near the top of the arch of the main axis of the anticline. It is interbedded with siliceous limestones and red marls. The face of the quarry exposes the rock for a distance of about 250 feet, and the bed has a maximum thickness of 28 feet, with a minimum of 7 feet at places along the outcrop. The dip of the bed is about 15° N. The gypsum is very compact, of a drab-gray color, and is uniform in appearance and quite free from impurities where it has not been altered by surface decomposition. In two or three places a strip of red clay follows the joints which cut the bed. The gypsum deposit is traceable down the center of the basin, and appears to be of inexhaustible quantity.

The deposits near Morrison, on Bear Creek, and on Deer Creek are evidently local beds in the same series that is found at Loveland, and outcrop in the upturned edges of the rocks a short distance east of the foothills. The extent of the beds is not known, but their thickness on Deer Creek is about 20 feet. The deposit at Perry Park is in the same geologic series and has been extensively worked. A detailed description of the locality is not available. In the Garden of the Gods, near Colorado City, where the rocks have fantastic forms and are found outcropping practically on edge, the gypsum bed is conspicuous because of its whiteness. The gypsum has a fine alabaster texture and shows narrow seams of so-called satin spar. From the beds on Fountain Creek material is derived from which statuettes of so-called alabaster and plaster of Paris are made. The deposits are of fine quality, but individual beds without clay seams or impurities are not large. Similar deposits are found at Canyon, on the Arkansas, and southward from this point to Trinidad; but no precise knowledge or record of them can now be given. In the southwestern portion of South Park, in the vicinity of the salt works, gypsum is known to occur, but has not been developed.

In the western part of the State, near the station of Gypsum, on the Rio Grande Railroad, between Leadville and Glenwood, and at the same geologic horizon on Roaring Fork, between Glenwood and Aspen, there are gypsum deposits which may prove to be of economic value.

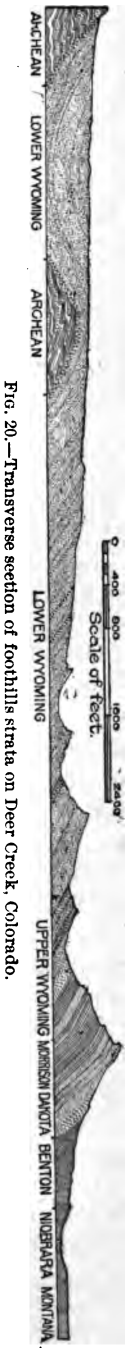


Fig. 20.—Transverse section of foothills strata on Deer Creek, Colorado.

In southwestern Colorado, to the east of the La Sal Mountains, in the area drained by the Rio Dolores, important deposits of gypsum occur in the Red Beds and also in lake deposits, which are probably of Tertiary age.

In the San Juan mining region, and also in the vicinity of Durango, gypsum occurs in the Hermosa formation, as has been noted by Mr. A. C. Spencer.[a] This formation consists of limestones, green sandstones, and shales, with some beds of gypsiferous shales.

In the vicinity of Newman Hill, at Rico, there is a bed of rock gypsum having a thickness of 30 feet in certain places. Mr. F. L. Ransome, who has studied the ore deposits of this place, has shown that the occurrence of the gypsum in the blanket zone is a matter of considerable theoretical and practical importance.[b] The gypsum has largely been dissolved, and the solution has been accompanied by the accumulation of a silty residue. In certain places where the gypsum occurs no ore is found, but where the gypsum has been dissolved away the blanket zone has been mineralized.

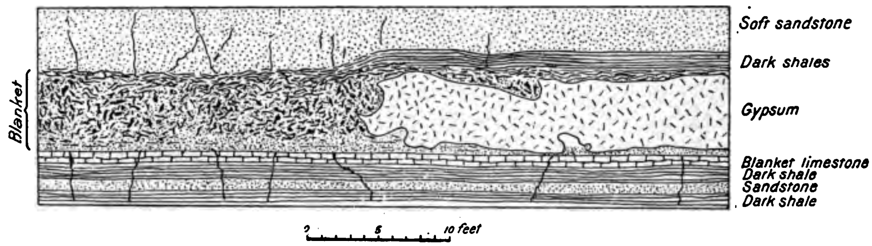


FIG. 21.—Diagramatic section through a portion of the Enterprise blanket, showing relation of the gypsum to the blanket, Rico, Colo.

Small bodies of gypsum of secondary origin, resulting from the reaction of the sulphate solutions of mine and ground waters upon limestones, are found in many of the mining districts. This has been recognized by Mr. Ransome as actually taking place in C H C Hill, but the gypsum formed at that place is merely a dull earthy crust on the limestone, and is evidently dissolved nearly as fast as it is formed, and consequently attains no considerable size.

GEOLOGIC RELATIONS.

The gypsum found along the eastern foothills of the Rocky Mountains is in a series of red sedimentaries which has usually been referred to the "Juratrias." The formations are destitute of fossils, and the gypsum was apparently deposited from landlocked bodies of sea water. The deposits in the west-central part of the State and in the Hermosa formation are of Carboniferous age.

[a] Geology of the Rico Mountains: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 48-54.

[b] Ore deposits of the Rico Mountains, Colorado: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 2, 1901, pp. 273-280.

GYPSUM DEPOSITS IN NEW MEXICO.

By H. N. Herrick.[a]

CHARACTER AND EXTENT.

Gypsum is found so generally distributed in New Mexico, and occurs in such vast deposits and in such variety of forms, that the

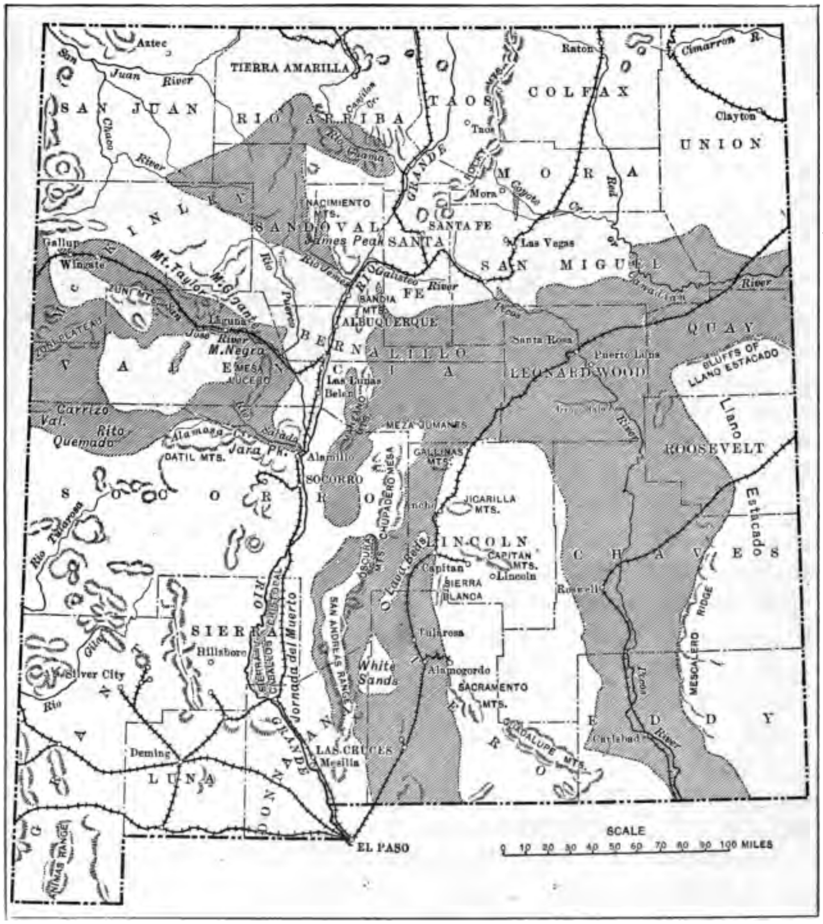


Fig. 22.—Map of New Mexico showing approximately the area of the Red Beds, which are gypsum bearing at numerous localities.

supply is practically inexhaustible. Until 1902, however, no attempt to utilize it in a commercial way had proved successful. A number

[a] In the preparation of this paper use has been made of the field notes and publications of Prof. C. L. Herrick.

of efforts have failed because of excessive freight rates and small market. Gypsum is used to a limited extent by the Mexicans, who generally have in their villages a pile of *hieso*, which is calcined in ovens as needed and used for plastering the interior of their houses. Some has also been ground and used as land plaster in attempts to reclaim alkali lands, the gypsum reacting in such a way as to transform the "black alkali" to a less harmful salt. Gypsum is the only substance which has been shown to benefit these lands, but its effect is slow and its use expensive. There is not as yet much demand for it for this purpose.

For the manufacture of plaster and cement there is but one plant in the territory, that of the Rock Island Cement and Plaster Company, located at Ancho, on the line of the Rock Island Railroad. At the time the works were visited only a small testing plant was in operation, a large mill being in process of construction. In the low, wooded foothills of the White Mountains, which surround this place, there are conspicuous exposures of gypsum and anhydrite. The following section was taken from the highest hill in the neighborhood, at a place where a quarry had been begun:

Section in foothills of White Mountains, New Mexico.

	Feet.
Soft, gray sand and shales	85
Limestone	7
Pure massive anhydrite	12
Earthy anhydrite	5
Massive anhydrite	15
Limestone	2
Anhydrite	4
Limestone	1
Massive anhydrite	35
Limestone	5
Gypsum, bottom.	

The material used is the disintegrated anhydrite and gypsum, which occur as a surface deposit and have a thickness in places of from 10 to 20 feet. This gypsum dirt or gypsite is simply scraped up, put through coarse screens, and calcined in iron hoppers, after which it is put through a 35-mesh screen and is ready for use. It is claimed that the organic and other impurities in the gypsite make the use of the usual retarder unnecessary, thus doing away with one of the principal sources of expense. The finished cement needs only to be mixed with from three to four parts of sand before using. It is light gray when set, and houses in which it is used as mortar or outside finish are not only neat in appearance, but resist weathering remarkably well.

GEOLOGIC OCCURRENCE.

With the exception of certain gypsiferous shales in the Cretaceous, the gypsum-bearing deposits in New Mexico occur in what are known as the Red Beds. The Red Beds have not been studied sufficiently as

yet to permit close classification. In the vicinity of Mesa Gigante three divisions are recognized, which are distinguished largely by their colors. The lower or Red division is the only one containing any considerable number of fossils. It is referred to the Permian on paleontologic grounds. Near the top of this division the gypsum horizons are generally found. Above the Red division is the Chocolate series, of a darker red, and at the top is the Vermilion series. The lowest division usually contains some bands of limestone or lime breccias, which are a very characteristic feature, and is of an average thickness of about 500 feet. The Chocolate division is about 600 feet in thickness and is composed of quartzites and gray and red sandstones, passing gradually into the loose, bright-red marls and clays of the Vermilion division. The Chocolate and Vermilion series have been referred to the Triassic and Jurassic for stratigraphic reasons, but it may be that they are only a continuation of the Permian. It can not be said with certainty that this threefold division is maintained throughout New Mexico, since detailed study has been possible at only a few localities. Considerable variation in lithology has been noted, and possibly the color is not a reliable guide. So far as observations have been made on the conditions of sedimentation they point to shallow-water deposition in the northern and northwestern portion of the Territory, and to the prevalence of conditions favorable to the deposition of limestones at recurring intervals in the southern part. For the purpose of discussion, the Territory may be divided into three regions. The eastern one lies principally in the valley of the Pecos, and is connected with the Red Beds area of northern Texas by an arm extending along Canadian River. The central division is drained by the Rio Grande and its tributaries. The western division is in the region of the Zuñi Mountains. These divisions are made simply for the purpose of discussion, and are not based on geologic differences; neither are they geographically distinct.

DESCRIPTIONS OF LOCALITIES.

EASTERN NEW MEXICO.

The largest area of the Red Beds in New Mexico lies in the eastern part of the Territory, principally in the valley of the Pecos. It has not been studied excepting in reconnaissance, but an attempt has been made to show its extent on the accompanying map.

Along Canadian River an arm of the Red Beds extends from New Mexico into Texas, connecting with the vast area in northern Texas, Oklahoma, and Kansas. These exposures are of interest since they show the continuity of the Red Beds and indicate that the conditions of sedimentation were similar over a wide area. The beds along the Canadian are exposed as a result of the removal of the Tertiary deposits which form the High Plains, or Staked Plains as they are called in

Texas and New Mexico. This has been accomplished by the river in the process of eroding its valley. From these exposures and the relations of the formation in general it may be inferred that the Red Beds are probably present under a considerable portion of the Staked Plains.

Lower Pecos Valley.—In this region the area of the Red Beds is relatively narrow as compared with the upper portion of the valley. It is limited by the Staked Plains to the east and the mountains to the west. There are frequent exposures of gypsum, and the presence on the map of such names as Salt Lake, Salt Spring, Alkali Flat, Tierra Blanca Lake, Arroyo Hieso, etc., indicates the general character of the country.

Plain west of the Upper Pecos.—This whole region is one of alkali flats, salt lakes, and sandy hills, with a few isolated peaks, such as the Cerro del Pino and Pedernal Mountain.

The western portion of the area, covered by the Antonio Sandoval grant, contains several especially large salt lakes, which have been a well-known and much-used source of salt as far back as history and tradition go. In most of these lakes the salt has been deposited on the bottom in layers from one-half inch to 3 inches thick, alternating with layers of gypsum. In the largest lake the upper layer of salt is about 8 inches thick, and the water is a saturated brine. In the banks of the depressions in which the lakes are located exposures of shales with bands of gypsum are found, and on the side of the Mesa Jumenez, on the southern edge of the plain, a thick bed of impure gypsum and anhydrite is exposed for miles. On the western edge of the plain are exposures of the Upper Carboniferous, which, however, dip toward the east at an angle that should bring the Permian to the surface before the lakes were reached. Wells sunk in the eastern part of the plain penetrate layers of gypsum, and it is evident that the gypsiferous horizon can not be far below the surface at any point. It is a curious fact that the water of these wells, as also that of the few springs, is not only brackish, but smells strongly of sulphureted hydrogen. Some of these wells are 20 miles from any place showing evidence of volcanic action, and the only explanation that suggests itself is that there may be some reaction between the calcium sulphate and organic matter in the soil which liberates this gas.[a]

Where Pecos River cuts the plain there is another exposure of the Permian with its beds of gypsum, and the streams are impregnated with salt and alkalies.

Coyote Creek.—To the north and west of the city of Las Vegas the Red Beds are frequently exposed, but thus far no extensive gypsum deposits have been encountered. The sequence of strata seems to be similar to that of the northwestern portion of the Territory, rather

[a] For more complete discussion see Johnson, D. W., Notes of a geological reconnaissance in eastern Valencia County, N. Mex.: Am. Geol., Feb., 1902.

than to that of the southeastern. Careful stratigraphic work is lacking for this region, but the existence of extensive deposits of copper in the shales of this series is especially noteworthy. In the valley of Coyote Creek, in Mora County, east of the town of the same name, is a very characteristic exposure illustrated in a general way by fig. 23. To the west is a great granite uplift, bearing on its summit fragments of the Carboniferous series, to the east is a sharp monocline dipping eastward, composed, apparently, of the sandy base of the Cretaceous, while the interval between contains the nearly vertical strata of the Permian or "Permo-Carboniferous," with the characteristic red sandstones and chocolate shales of the former and the bedded fossiliferous limestones of the latter division. For many miles north of this locality the carbonaceous and micaceous shales contain disseminated flakes and larger nodules of copper, replacing organic matter, the interbedded sandstones here having been converted by local metamorphism into dense quartzites. The whole formation farther north is covered by an extensive flow of recent basalt.

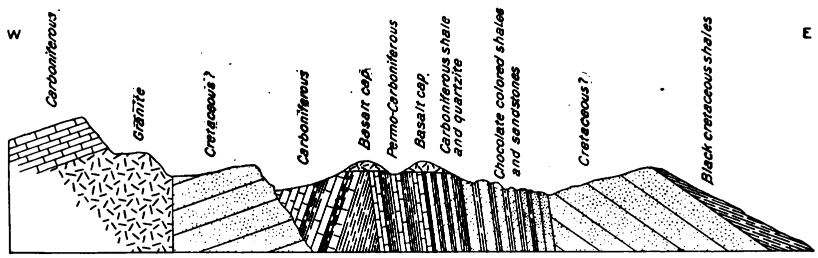


FIG. 23.—Diagrammatic section north of Lucero, N. Mex., in valley of Coyote Creek.

Southeast of Las Vegas.—Passing southward from Las Vegas strata successively lower in the series are crossed, the upper Red Beds appearing in well-defined escarpments about 20 miles southeast of Las Vegas. Pecos River is bordered by exposures of the Red Beds for a large part of its lower course. The southeastern boundary of the Anton Chico grant is marked by a profound fault, known locally as El Alto de Los Enteros, and the walls of the canyon for several miles below display the effects of local metamorphism. A remarkable exaggeration of the sandy strata in R. 21 E. produces a sharp curvature in the river north of the Pecos grant. These sandy strata, occupying a position above the gypsiferous layers, are impregnated with asphalt, and have given rise to great expectations of oil. The record of a well upon the Perea grant, bored to a depth of 770 feet, showed a prevalence of gypsiferous shales beneath the asphalt layer. The existence of soluble deposits in these beds is proved by the numerous "sink holes" in the region north of Santa Rosa. On descending the Pecos successively lower strata of the Red Beds are reached, till in Arroyo Salado gypsum and foliated limestone are found at the surface.

RIO GRANDE VALLEY OR CENTRAL REGION.

Chama Valley.—In the absence of personal investigation north of the Jemez Range reference is here made to Professor Cope's account of the stratigraphy north of the Nacimiento Mountains.[a]

The region seems to be very similar to that south of the Nacimiento Mountains, on the headwaters of the Rio Jemez and Rio Puerco, described below. In the canyon of the Cangilon, which is tributary to the Chama, Professor Cope found the Red Beds, with layers of gypsum 50 feet thick in places, separated from the lowest Cretaceous by an interval of about 850 feet of mud-brown sandstone. Below the gypsum is a lemon-yellow band, and below this are beds of vermilion-red sand. The gypsum was supposed to mark the top of the Jurassic, the thickness being given as 600 feet, below which were 1,000 feet of Triassic, the bottom of which was not seen. The mud-brown sandstone above the gypsum is regarded as the equivalent of Cretaceous No. 1 of Hayden's section at Colorado Springs. Above this is Cretaceous No. 2, 1,500 feet thick, composed mainly of shales, and this is followed by the sandy Cretaceous No. 3, also 1,500 feet thick. Professor Cope reports the lower beds of the red series to be of fresh-water origin, as they contain unios and saurian remains. He also states that the Jurassic beds contain conglomerate lime strata and copper.

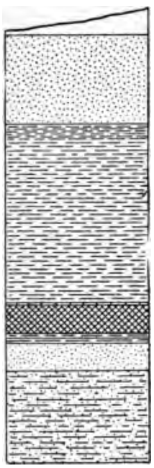


FIG. 24.—Section west of Nacimiento Mountains, New Mexico.

Headwaters of the Rio Puerco and Rio Jemez.—All along the western base of the Nacimiento Mountains are exposures of the Red Beds with thick bands of gypsum and gypsiferous shales high in salines (fig. 24). The Rio Salado, which is a tributary of the Rio Jemez, is so salty that its water is unfit for domestic use. It derives its salt from the formations along the western base of the Nacimiento Mountains, and carries a great part of the salt and alkalies deposited by the Rio Grande on the flats along its valley above the mouth of the Puerco. The Rio Puerco also flows along the western edge of the Jemez Range, farther north than the Salado, and there obtains the salines and alkalies and the dark-red sediments to which it owes its name. In this region there are deposits of copper which are mined at Copper City, on the western slope of the range. The copper occurs in a sort of

[a] U. S. Geog. Surv. W. 100th Mer., vol. 4.

loose conglomerate of the Lower Permian, and the proximity of the gypsum beds in this and other places has led prospectors to regard gypsum as a favorable indication when looking for copper.

In the region near Jemez Peak the coloration of the exposed Permian is especially brilliant, the bright-red bands of sandstone and shale contrasting with the white gypsum beds in a most startling way.

On the western slope of the Nacimiento Mountains the base of the "Permo-Carboniferous" series is well exposed, consisting of earthy limes and shales, often exceedingly fossiliferous. The narrow bands of lime breccia with included fragments of clay ironstone, everywhere characteristic of the transition beds throughout the Territory, are generally present. Conglomerates composed of materials from the granite axis of the range constitute another characteristic feature and furnish evidence of littoral conditions.

East of the Sandia Mountains.—East of the Sandia Range, which is formed by an uplift of granite, capped by Upper Carboniferous limestones and quartzites, is a succession of faults, the effect of which is to bring to the surface successive portions of the Red Beds and overlying Cretaceous. The enormous development of the massive red sandstones of the lower portion of the series, as exposed east of Tijeras Canyon, is very characteristic. These frequently contain trunks of trees, often altered to copper and iron ores. Above this red division are exposures of gypsum and anhydrite uniformly reposing on the vermicular shales elsewhere noted in this paper. Curiously enough, the anhydrite seems at this point to be at or near the top of the Red Beds, although it is impossible certainly to determine whether the juxtaposition to the Lower Cretaceous is not due to dislocation. In shales a short distance above a quartzite which here forms the top of the "Permo-Carboniferous" was found a series of fossils of undoubted Permian age. The remainder of the Red Beds have yielded no other fossils in this region than the tree trunks already mentioned. The prevailing sandy character and the inclusion of granite fragments in the Red Beds sufficiently indicate their littoral character at this place.

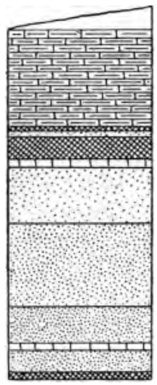


FIG. 25.—Section northwest of Pyramid Mountain, New Mexico.

East of the Manzana Mountains and Socorro.—The region immediately east of the Manzana Mountains resembles the Sandia region and offers numerous exposures of the red, indurated sandstones and shales. Southward, however, calcareous beds are found in the section, and the

formation resembles more or less that of the Red Beds of the southeastern part of the Territory. East of the town of Socorro are numerous extensive escarpments embracing hundreds of feet of limestone and gypsum or anhydrite not observed farther north. Fig. 25, which is a section taken northwest of Pyramid Mountain, shows the

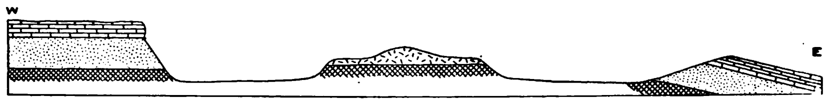


FIG. 26.—Section at Pyramid Mountain, New Mexico, showing basalt cap lying on gypsum.

existence of about 200 feet of earthy limestone above a still thicker series of sandstones and interbedded anhydrite and gypsum. Twenty miles northeast of Socorro is Pyramid Mountain, which is an isolated basaltic cone reposing directly upon a gypsiferous member of the Red Beds (fig. 26).

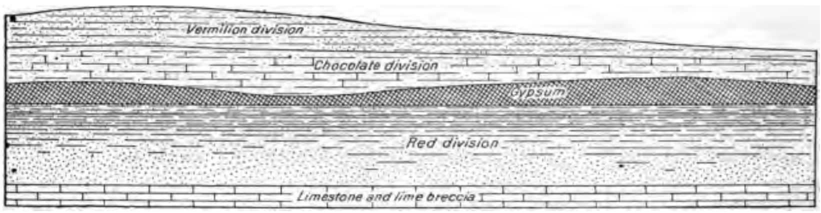


FIG. 27.—Section at Mesa Gigante, north of Rio San Jose, N. Mex.

Valley of the San Jose.—An area of the Red Beds occurs in the country traversed by the San Jose. It is bounded on the north by the extensive Mesa Gigante and Mesa Negra, the southern escarpments of which present very complete sections of the Red Beds series up to the Cretaceous. The threefold division is here very conspicuous. At

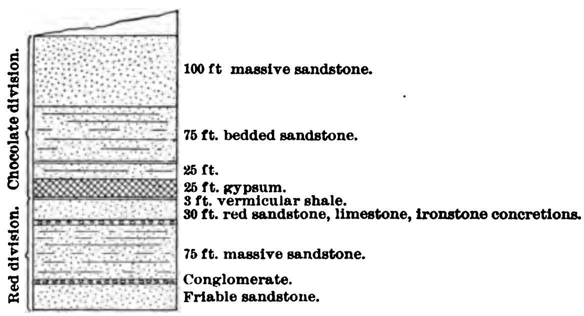


FIG. 28.—Section at El Rito, New Mexico, 8 miles east of Laguna.

the base is a comparatively small series of limestones and shales, followed by red sandstones and marls, pink sandy marls, and white sandy marls, to the base of the gypsum deposits, which are irregular, often lenticular in shape. The chocolate beds of sandstones and shales are recognized by their characteristic color, and are followed by the

so-called Vermilion division. The gypsum varies in thickness from 25 to 75 feet and in this region occupies a rather constant horizon. Beneath it a vermicular shale 3 to 5 feet thick is very regular in its

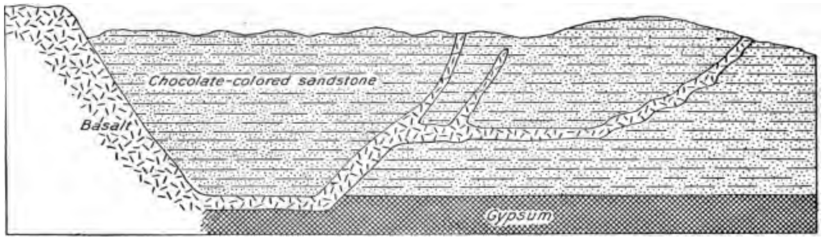


FIG. 29.—Section northeast of El Rito station, New Mexico, showing basalt dike penetrating the gypsum-bearing series.

occurrence. The gypsum is especially well exposed near the western boundary of the Quelites grant, where massive anhydrite occurs in beds over 50 feet thick. An extensive fault and monocline running north and south separates the Red Beds from the Cretaceous to the east. The accompanying sections at Mesa Gigante (fig. 27) and at El Rito, near Laguna (fig. 28), show the relations of the gypsum, and the curious interpenetration of basalt, which is of common occurrence around the margin of the great Mount Taylor lava flow, is shown in fig. 29.

Valleys of the Rio Salado and Rio Alamosa.—The salty stream called the Rio Salado, entering the Rio Grande near Alamillo, drains an area containing extensive exposures of the saline and gypsiferous Red Beds. Nowhere are these more prominent than in the conspicuous escarpment extending from Mesa Lucero to Jara Peak. Here the deep-water conditions prevailing in southeastern New Mexico repeat themselves, and about a thousand feet of the upper Red Beds are filled with limestone, with gypsiferous shales and massive beds of anhydrite (fig. 30). The lower part of the series consists of the quartzites and red shales of the Red division.

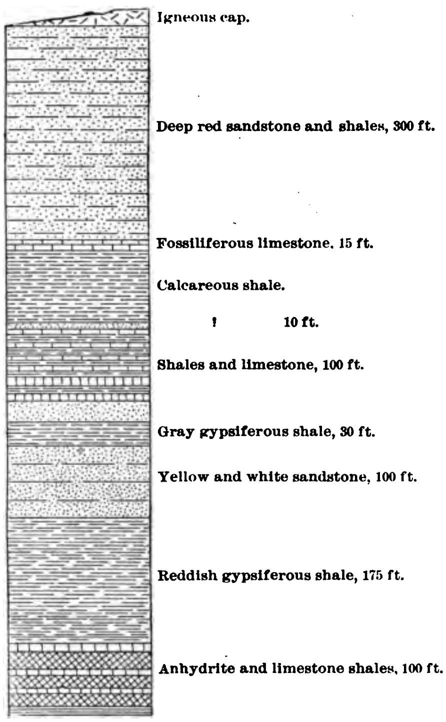


FIG. 30.—Section of bluff on Rio Salado, 30 miles west of Belen, N. Mex.

The limestone beds near the top of this escarpment afford numerous fossils, a critical study of which should determine the age of the beds.

Region of the Oscuro and San Andreas mountains.—The western slopes and foothills of the Oscuro and San Andreas mountains expose strata analogous to those of the Socorro region, with here and there extensive deposits of anhydrite and gypsum. The same conditions also prevail east of the Caballo and San Cristobal ranges. The great plain known as the Jornado del Muerto is evidently underlain at no great depth by deposits of the Red Bed series

The white sands.—The white sands constitute one of the largest and most remarkable accumulations of gypsum known (see Pl. XVIII). This deposit is in Otero County, and is a tract of dunes of nearly pure granular gypsum, covering about 350 square miles. The deposit is roughly triangular in outline, about 18 miles wide at the southern end, and about 35 miles long. It is bounded on the north by a remarkable flow of basalt 20 to 40 feet thick, the sound of flowing water beneath which can be heard. This water issues from the southern edge of the flow as a strong stream, slightly impregnated with salt and alkali. It soon sinks into a flat covered with efflorescence of salt and alkalies. On the west is the abrupt escarpment of the San Andreas, a granite foundation supporting a vast series of sedimentary rocks dipping toward the west and embracing a portion of the lower Carboniferous, and the lime and quartzite of the Permian. This escarpment is separated from the plain by a profound fault, adjacent to which numerous diorite dikes penetrate the stratified series in all directions. Numerous and profound cross faults filled with quartz, spar, iron, and copper infiltration extend from top to bottom of the series. On the east the same conditions prevail 35 miles distant, forming the escarpment of the Sacramentos.

To the south is an open plain broken by the Jicarilla Mountains, and to the northeast the massive Sierra Blanca rises over 10,000 feet, to the base of which cling the shattered fragments of all the stratified series represented in southeastern New Mexico, from the Burlington limestone to the Fox Hills Cretaceous. In an embayment between the White and Sacramento mountains, east of the ancient town of Tularosa, is a large depressed area covered with broken bluffs presenting the eroded edges of the gypsiferous Red Beds or Permian series, which undoubtedly forms the floor of the salt plain.

In this region there have been profound disturbances, and the inference is that the great saline plain has been left undisturbed while the corresponding formations have been thrust up on either side.

In the plain itself, a few miles west of Tularosa, is a small intrusive cone near which are several warm saline springs which have built up for themselves mounds of considerable height. The water from these springs soon sinks into the earth, leaving salt flats covered with a

VIEW OF THE WHITE SANDS, NEW MEXICO.

grayish-white efflorescence. At the northern edge of the white sands is a salt lake which has long been a valuable source of salt for the ranches in the neighborhood, and near the southeastern corner of the sands themselves is another still larger salt lake. Where arroyos cut the plain, and in the banks of the salt lakes, are exposures of shale and gypsum, which prove that the gypsiferous horizon so prominent on either side of the plain can not be far below the surface at any point.

In the salt flats the ribs of gypsum rise in successive ridges, and the action of the elements soon breaks up the exposed crystals into small grains which are carried by the winds hither and yon. A short examination shows that these great drifts are simply sand dunes collected from the gypsum sand formed, as above stated, on the surfaces of the lakes. The salt and alkaline salts are also driven with the gypsum, but on account of their solubility do not remain in the dunes. These dunes lie to the southeast of the flats, whither they are driven by the prevailing winds, and not only cover a large part of the salines themselves, but form a growing fringe to the east and south. [a]

ZUNI OR WESTERN REGION.

In the vicinity of Gallup and to the north of Fort Wingate the Red Beds are well exposed. From the top of the Carboniferous limestones and quartzites to the sandy exposures north along the railroad at Coolidge are numerous disconnected exposures of marls, sands, and gypsiferous shales, with beds of more massive gypsum and the characteristic ironstone breccias of the Permian. The upper part of the Red Beds, consisting of massive variegated sandstones, forms the picturesque bluffs and cliffs of the Zuni and Wingate sandstones, corresponding to the Chocolate and Vermilion series described in the region of Mesa Gigante. The celebrated Navajo Church is carved from the upper members of the series. West of Gallup a similar sequence can be observed from the railroad, and the continuity of the formation in the Zuni region can easily be traced.

In the valley of the Rito Quemado and in the escarpments of the Carrizo Valley fine exposures of the gypsiferous series may be seen. Gypsum is also associated with the salt in the neighborhood of the Zuni Salt Lake.[b] East of Rito Quemado gypsiferous marls apparently form the surface over a large area.

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[a] Herrick, C. L., Geology of the white sands of New Mexico: Bull. Hadley Laboratory, Univ. of New Mexico, pp. 12-13.

[b] Report of a geological reconnaissance in western Socorro and Valencia counties, N. Mex.: Bull. Hadley Laboratory, Univ. of New Mexico, Vol. II, Pt. I.

GYPSUM DEPOSITS IN ARIZONA.

By Wm. P. Blake.

CHARACTER AND EXTENT.

There are several known localities in southern Arizona where gypsum can be obtained in quantity. The following may be particularly noted:

(1) The Santa Rita Mountains, Pima County, southeast of Tucson.

(2) The low hills along the course of San Pedro River in Cochise and Pinal counties.

(3) The Sierrita Mountains south of Tucson.

(4) The foothills of the Santa Catalina Mountains north of Tucson.

(5) Fort Apache Reservation, in Navajo County.

The Sierrita and Santa Catalina mountain localities are in Pima County. At the latter gypsum has been quarried for economic purposes. In addition, deposits have recently been developed to a limited extent in the vicinity of Woodruff and Snowflake, but no description of the deposits at these places can be given at this time.

The locality in the Santa Rita Mountains is not far from Rosemont, and is about 10 miles south of the Southern Pacific Railway. It is on the eastern side of the range, a few miles east of the Helvetia copper mines, in the midst of a hilly region. The gypsum appears to be in beds of great thickness and extent. The croppings form low hills of considerable magnitude, but they are so much eroded, rounded, and softened by weathering as to make observation upon the stratification, thickness, and the relations of the gypsum to the inclosing rocks difficult. The formations are supposed to be upper members of the Carboniferous, Devonian strata having been identified near Rosemont, but they may be found to be Triassic. There has not yet been an opportunity for a careful investigation. The few sample specimens obtained show a compact granular structure and are somewhat veined with dark-colored streaks. Some specimens resemble alabaster. This locality of gypsum was noted in the report to the governor of Arizona for the year 1896, and again in the report for 1899, page 127.

The gypsum along San Pedro River occurs in horizontal beds, probably of Pliocene or post-Pliocene age. The strata are soft, unconsolidated gray sandstones and clays, and appear to be the lower members of the same series in which the beds of diatomite and volcanic ash are found. The gypsum is interstratified conformably in

comparatively thin layers or seams, rarely more than a few inches in thickness. These layers appear to have been formed subsequent to the deposition of the strata by crystallization from the infiltration of gypseous solutions. The mineral occurs as selenite, and, also, in the fibrous form, as satin spar.

The Sierritas locality is in connection with the copper-ore deposits of the azurite groups in massive limestone. At this locality the gypsum may be regarded as originating from the action of solutions of copper sulphate and of iron sulphate upon the lime carbonate, resulting in the formation and deposition of copper carbonate, of limonite, and of lime sulphate.

The locality north of Tucson, in the foothills at the western end of the Santa Catalina Range, has afforded a supply for the production at Tucson of plaster of Paris of good quality, which has been used locally in construction. A considerable quantity of the product was used in making the interior decorations of the cathedral. The crude rock is brought in from the quarry by Mexican teamsters, and little is known in regard to the geologic position of the deposit. It is probable that it occurs in strata of Triassic age, flanking the ancient gneiss of the Catalina Mountains.

Gypsum occurs in the form of selenite in plates of considerable size on the Fort Apache Reservation, in Navajo County. It is found at three places in such quantity that it is proposed to use it in the construction of houses which are to be built for the Indians.

GYPSUM DEPOSITS IN UTAH.

By J. M. Boutwell.

CHARACTER AND EXTENT.

The mineral resources of Utah are still so little known that a description of any class of deposits in that State is necessarily incomplete. Large deposits of gypsum have been found in several localities in Utah, and it is not improbable that others will be discovered in the course of the present active economic development.

The more important known deposits occur in the central and southern portions of the State, in Juab County, east of Nephi; in Sanpete and Sevier counties, near Salina; in Millard County, at White Mountain, near Fillmore, and in Wayne County in South Wash. They are all of the rock-gypsum type, except the one near Fillmore, which is in the secondary form of unconsolidated crystalline and granular gypsum blown up from desiccated playas into dunes. Deposits are also known in Emery County, about 40 miles southeast of Richfield; in Kane County, near Kanab; in Grand County, between Grand River and the La Sal Mountains; in Sanpete County, near Gunnison; in the eastern part of Washington County (?), between Duck Lake and Rockville, and at other places. Recently enormous deposits of gypsum have been reported from Iron County, at points so far from lines of transportation, however, as to render their exploitation impracticable for the present.

In general, a comparison of these deposits with others studied by the writer in this country and Canada shows them to be unusually extensive and of excellent quality. In this paper the deposits at Nephi, Salina, White Mountain, and South Wash will be briefly described.

ECONOMIC DEVELOPMENT.

Nephi deposits.—This immense mass of rock gypsum is located in Juab County 1 mile east of Nephi, on the south side of the entrance to Salt Creek Valley. (See Pl. XIX, *A*.) It has been worked for the last fifteen years practically without interruption, and is the only deposit in Utah which is now being exploited to any extent. In view of this fact a brief visit to this locality was made in December, 1902, and (despite a heavy fall of snow which handicapped outdoor work) information was procured which forms the basis of the present statement.[a]

[a] For much of the information here presented the writer is indebted to Mr. F. A. Hyde, manager, secretary, and treasurer of the Nephi Plaster Company, and to Mr. James Jackson, superintendent in charge of both quarry and mill, who courteously afforded every facility for studying the occurrence and exploration of this deposit and furnished important information.

A. ROCK-GYPSUM DEPOSIT 1 MILE EAST OF NEPHI, UTAH.

B. BED OF GYPSUM ON MESA 15 MILES NORTH OF KING CITY, MONTEREY COUNTY, CAL.

This deposit was known before the town of Nephi was settled, and has probably been known to the whites for nearly eighty years. About thirty-five years ago a claim 600 by 1,500 feet in dimensions was formally located, and in 1882 this was patented by John Hague and others under the name of the Juab Plaster and Mining Claim. After small intermittent shipments to Salt Lake City in 1887, under the management of Messrs. Hyde, Hague and Whitmore, rock gypsum was quarried and burned in sorghum pans for local consumption. During the following year, encouraged by the rapidly increasing demand, these persons incorporated their company and erected the nucleus of the present efficient plant.

The rock is now obtained by blasting from an extensive open cut, and is trammed by gravity to the works. The present plant, which is the product of repeated enlargement, though not extensive, is very complete. It includes (1) a mill which is fitted with 1 nipper, steel grinder, round buhrs, 3 chain elevators, 2 two-flue 8-foot calcining kettles, a mixing plant, etc.; (2) a complete cooper shop, and (3) storehouse. Ample power is supplied by a turbine driven by water taken from Salt Creek and conducted by a sidehill ditch to a point high enough above the mill to afford sufficient fall.

The output from this plant includes dental, casting, finishing, land, and hard plaster, each appropriately prepared for its special uses. A large and increasing demand is supplied throughout the Great Basin region, and shipments are made as far as Grand Junction on the east and Los Angeles and Hawaii on the south and west and Victoria on the north.

Other bodies of rock gypsum outcrop at several localities higher up in Salt Creek Valley. Some of these have been worked on a small scale, but owing to their less suitable location and poorer quality they have been abandoned.

Salina deposits.[a]—These deposits have been worked within a few years to some extent for general commercial uses, but chiefly for local needs. Rock gypsum of good grade occurs in a bed of considerable thickness, and was recently quarried and ground in a small mill. At present, however, active operations have been suspended.

White Mountain deposits.[b]—This vast deposit has been worked only on a small scale and for local needs. Of the three types of gypsum which comprises it, gypsiferous clay, gypsum sand, and mounds of loose small crystals, the last probably offers the greatest commercial possibilities. This unconsolidated crystalline gypsum, probably of a

[a] Information given in this sketch regarding these deposits has been gathered from various sources, including Mr. James Jackson, superintendent of the Nephi Plaster Company.

[b] Statements in this paper about these deposits are based upon personal communications to the writer by Mr. G. K. Gilbert and descriptions which he has published in his work on Lake Bonneville, Mon. U. S. Geol. Survey, vol. 1, pp. 222-223, and Pl. XXXV.

high degree of purity, lies upon the slopes of elevations composed of volcanic rocks, and forms mounds or dunes. "Perhaps no gypsum deposit in the world is so easily exploited as this. It needs merely to be shoveled into wagons and hauled away. Mr. Russell estimates that the dunes contain about 450,000 tons, and a much larger amount can be obtained from the playa. The depth of the playa deposit was not ascertained."[a]

South Wash deposits.—Occurrences of rock gypsum observed in Wayne and Garfield counties by Mr. G. K. Gilbert in 1871 (then geologist on the Wheeler Geographical Survey) are described by him as so extensive that one could walk in one direction for about 2 miles without stepping off from gypsum. So far as known, these extensive deposits of rock gypsum and gypsum sand have never been utilized for commercial purposes. The only known use made of them was for exhibition purposes, when, under the auspices of the Deseret Museum, of Salt Lake City, 20 tons of the crystalline variety, selenite, was shipped from the South Wash deposit to Salt Lake City. Professor Talmage states that "the huge geodes of selenite or crystallized gypsum on the deserts of Wayne and Garfield counties, and the associated gypsum of other forms, such as plaster-stone and gypsiferous sand, will doubtless prove of value, but, chiefly owing to the inaccessible nature of the region, deposits have not been touched in the way of commercial development."

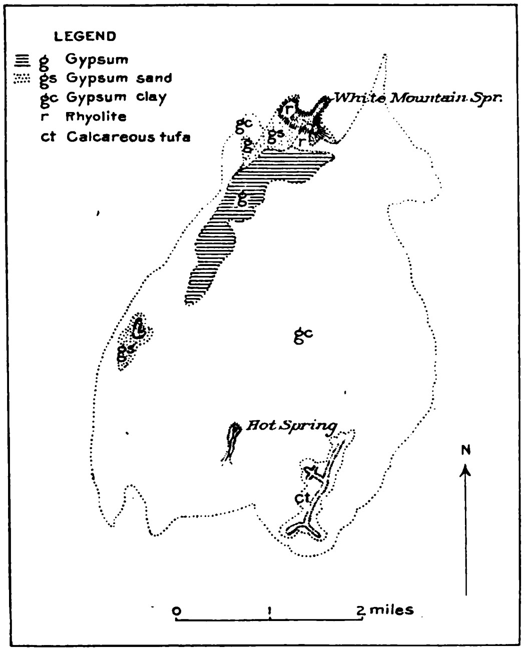

FIG. 31.—Map showing extent of White Mountain, Utah, gypsum deposit.

DESCRIPTIONS OF LOCALITIES.

Nephi deposit.—This is the largest thoroughly known deposit of rock gypsum in Utah, and one of the largest in the world. It forms the entire mass of a prominent spur at the entrance to Salt Creek Valley, and outcrops from the level of the creek up the slope in a south-

[a] Gilbert, G. K., Lake Bonneville, Mon. U. S. Geol. Survey, vol. 1, p. 223.

easterly direction in the form of a vertical bed or lens (see Pl. XIX). The exposed portions of this body are from 275 to 300 feet in thickness, 500 feet in height along the bedding, and at least 700 feet in length along the strike. The length depends upon whether the deposit thins out along the strike is faulted or continues unbroken. Owing to a thick blanket of snow which covered the upper portion of the gypsum croppings to a depth of 2½ to 3 feet at time of visit, this could not be observed. The croppings are reported, however, to have been traced southeastward for several hundred feet to the main divide.

Although the total thickness of the deposit is made up of gypsum, the character of the rock varies somewhat in different beds. A general section from foot to hanging wall includes the following:

General section at Nephi, Utah.

	Feet.
Interbedded shale and gypsum, marl, and gypsum dirt	30
Rock gypsum, "first-class"	65
Rock gypsum, fractured, occasional bands of disseminated calcareous particles, etc.	75
Rock gypsum, "first-class"	55
Gypsum and shale, transition to shale	50

The second member affords all of the present output; the third, though gypsum of good quality and easily extracted, owing to its fractured state, is not quite so pure, while the fourth is of excellent grade and will probably be operated in conjunction with the second by the open-cut method in the near future.

The first-class rock is massive, dense, lusterless, and light grayish brown. The chief variations are a mottled, whiter, harder facies, which occurs at the top of the main bed exploited (No. 2) and "shaly" bands. The bands are zones, in which small, brown, angular fragments are included in white and brown rock gypsum. These fragments prove on analysis to be more calcareous than the balance of the rock.

Reliable analyses of gypsum are rare, so that there remains much to be learned regarding the desirable qualities in its composition. In view of this and of the significant facts developed, two analyses are here given, No. 1 of a sample of first-class rock gypsum from the second member, No. 2 of "shaly" portions in waste or rejected gypsum rock from the third member.

Quantitative partial analyses of gypsum from Nephi, Utah.

[Analyst, Dr. E. T. Allen.]

No. 1.

CaO	35.29
MgO	trace.
H_2O	15.88
SO_3	48.14
CO_2	.65
Cl	trace.
	99.96

No. 2.

Insoluble	0.45
CaO	38.46
MgO	.24
$Fe_2O_3+Al_2O_3$	.14
K_2O	.19
Na_2O	.07
H_2O	12.69
SO_3	39.53
CO_2	7.73
Cl	.04
	99.54

From these results Doctor Allen determines that the first sample is made up of 76 per cent gypsum, 22.5 per cent anhydrite, and 1.5 per cent calcium carbonate (limestone ?); and that the second is composed of 60.5 per cent gypsum, 22 per cent anhydrite, 17 per cent calcium carbonate (limestone ?), and 0.5 per cent magnesium carbonate (dolomite ?).

Perhaps the most important feature brought out by these results is that the first-class rock, as well as the "waste rock," includes between 22 and 23 per cent of anhydrite. The significance of this fact lies in the practical influence of the anhydrous material on the action of the combined product; for although when gypsum is calcined the largest portion of water is driven off, it is generally regarded as essential to its suitability for plaster that some of its water be left. "When it is heated to 100–120° C. it gives up three-fourths of its water very quickly, but it requires a temperature of from 200–250° to expel the remainder. * * * If gypsum has been heated to a little over 200°, thus being deprived of all of its water, it becomes dead burnt, and takes up water very slowly and without hardening."[a]

It would seem, therefore, that in so far as natural anhydrous calcium sulphate (anhydrite) is like artificially dehydrated gypsum in actual practice, the presence of anhydrite would at least retard "setting." In the manufacture of patent cements, however, heating to 600–700° F., when carried on in conjunction with the addition of sulphuric acid, borax, and cream of tartar, etc., is stated to give a product, which, after setting very slowly, becomes exceedingly firm and hard.[b] It is probable that anhydrite occurs in a large percentage of the gypsum deposits, so that further reliable analyses of other gypsums which made plaster of good setting quality are much to be desired.

The presence of calcium carbonate (limestone) to the extent of 17 per cent in the rock which is sorted out for rejection may be advan-

[a] Thorp, T. E., Dictionary of Applied Chemistry, vol. 1, p. 406.
[b] Wilder, F. A., Iowa Geol. Survey, vol. 12, p. 157.

tageous for special uses. In the preparation of certain hydraulic cements limestone is considered a valuable constituent. The significance of the content of potassium, magnesium, and sodium in connection with the origin of these deposits is considered hereafter.

Several other deposits of value are known in the Salt Creek Valley east of the main body, the most important of which is on the north side of the creek, about one-half mile east of the Nephi plaster mill. They include rock gypsum of good grade. In many localities they would be exploited, but they are so near the great body at the mouth of the valley that they are not worked.

Salina deposits.—On the General Land Office map these deposits are shown as extending in a northeast-southwest belt from Mayfield, in the southern portion of San Pete County, to Salina, in the northern part of Sevier County, a distance of about 18 miles. They were not visited by the writer, but are known upon reliable authority to be of the rock-gypsum type.

White Mountain deposits.—In Millard County, about 8 miles west of Fillmore, occur very extensive and valuable secondary deposits of gypsum. They include deposits of gypsiferous clay, covering an oval area approximately 3 by 5 miles in extent; two areas of gypsiferous sand, one one-half of a mile long and one-third of a mile wide, the other an irregular area approximately one-half a mile square, and an elongated area of gypsum about 2 miles long and one-half mile wide. (See fig. 31.) The gypsum contained in each is believed to have been transported by streams from its original position in the mountains on the east and redeposited with detritus in the White Mountain playa. It is in the form of minute crystals. To a considerable extent these have been freed from inclosing sediments by desiccation, reconcentrated by the wind, and collected into dunes of pure gypsum.

South Wash deposits.—This deposit was not visited by the writer. The present statements regarding it are from an illustrated description by Prof. J. E. Talmage, of the Utah State School of Mines.[a]

Here and there along the gorges are outcrops of gypsum varying in degrees of purity, and seams of this material cut through the country rock in all directions. In places veins of satin spar, as thin as a sheet of note paper, or even an inch in thickness, can be traced for many hundreds of yards upon the surface of the ground in uninterrupted course, except for intersecting planes of the same material. On the walls of the ravines and canyons places are seen where spar veins cross and recross each other with bewildering profusion. * * * Gypsum in all varieties may be found within a short radius. Fibrous and scaly laminæ, plaster stone or rock gypsum in masses, lumps of pure alabaster, and fragments of selenite crystals are scattered along the washes and strewn upon the bench lands. * * *

The crystals occur in a cave, and this is inclosed by a thick shell forming a mound. * * * This selenite mass seems to have been left exposed by the weathering of loosened friable sand and clay, of which the hill whereon the mound is situated is composed. * * * Prisms of perfect form and varying in length from 1 to 5 feet

[a] Science, vol. 21, pp. 85–87.

and in weight from 10 to 100 pounds are of frequent occurrence. One of the most regular yet taken out is 4 feet long and the widest faces are 6 inches across. Cleaved slabs are obtainable 6 feet in length and 2½ feet in breadth. One of the longest perfect prisms yet obtained extends 51 inches, and from one of its faces 19 smaller crystals sprout. Twins are common, as are also compound terminations of very complicated structure. [a]

Specimens from this locality are on exhibition in the National Museum and other institutions.

Since studying this occurrence, Professor Talmage has found a half dozen more geodes, and "has no doubt that the entire deposit is gypsiferous."

GEOLOGIC RELATIONS.

Nephi deposits.—The geologic structure of this region is exceedingly complicated, and only its broadest characteristics can be stated now. The Nebo massif to the north, composed of Paleozoic rocks, appears to have been elevated above the tract of Jurassic and Tertiary rocks to the south and east by faulting along the northeast-southwest zone. The tract on the southeast side of this possible fracture zone includes a considerable thickness of olive and gray calcareous shales, buff limestone, black paper shales with massive interbedded members, gray sandstone, reddish conglomerate, and a heavy series of grayish-brown sandstone. The general eastward dip is frequently lost in excessively folded and tilted structures. The geologists of the Wheeler Survey were of the opinion that an unconformity between the Tertiary and Paleozoic appears in this valley.

The area in the immediate vicinity of the main gypsum deposit lies on the southeast side of the possible zone of fracture, and the beds are extremely deformed. On the north side of the mouth of Salt Creek Valley gray and black shales stand vertical and strike northeast; farther east they swing into east and southeast strikes and dip to the north, thus forming the nose of an anticline which plunges steeply northward. The gypsum bed lies on the south side in a series of buff limestones and gray and buff calcareous shales. The strike of this series is northwest-southeast, and the general dip is vertical or steep to the southwest, except where local variations occur adjacent to fissures or closely appressed folds. The gypsum body stands nearly vertical, dipping locally 85° SW. between shale walls, and strikes southeasterly. Owing to the snow which covered the ground at the time of visit, neither the upper nor lower contact nor either limit along the strike was observed, so the precise nature of the occurrence can not be positively stated. It appears, however, to be in the form of a bed deposited contemporaneously with inclosing sediments, and it is probably either a thick lens which pitches rapidly along the strike or a bed which has been terminated in either direction along the strike by faulting.

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[a] Idem, p. 86; also see description by Moses, Alfred J., One of the gypsum crystals from the cave at South Wash, Wayne County, Utah: Science, vol. 21, pp. 230-231.

Although the study of the region was too hasty to obtain sufficient data for a complete explanation of the origin of the deposit, general observations, together with facts brought out by the analyses, afford accordant evidence for an opinion. The bedded structure of the gypsum, the agreement of this bedding with that of the country rock, the interbedding of the wall rock and gypsum, and the occurrence in the same series in this neighborhood of rock salt, common salt, and gypsum of various degrees of impurity tend to indicate a sedimentary origin. The presence of about 17 per cent calcium carbonate, one-half of 1 per cent of magnesian carbonate, and minor amounts of potassium and sodium salts afford additional basis for the belief that this gypsum is the product of deposition from surface water bodies, such as inland lakes, lagoons, or bayous.

The geologic date of this deposition can not be settled until further paleontologic evidence has been obtained. The rocks of the region are indicated on the geologic map of the Wheeler Survey as Jurassic, and in the report it is stated that "The Jurassic rocks are everywhere found to be very gypsiferous, and in some places good workable beds of gypsum are seen. One of these beds occurs at Salt Creek, near Nephi.[a]

Salina deposits.—The country rock in which the principal deposits occur is reported to be made up of dark-red shales and sandstones. The general area occupied by this belt of gypsum was mapped by the geologists of the Wheeler Survey as Jurassic and Tertiary,[b] and mention of "some fine selenite crystals from the Salt Mountains just south of Salina,"[c] where Jurassic was mapped, suggests the probability that this deposit was considered of Jurassic age.

White Mountain deposits.—High-lying beaches and related shore phenomena indicate that at an early geologic period the greater portion of Utah was submerged beneath the waters of an extensive inland sea.[d] When the level of this lake was lowered by drainage over its rim and by desiccation its extent steadily decreased and the bottom became exposed. Then the great Bonneville basin became subdivided into a number of smaller separate basins. In the lowest depressions of these basins lie either the existing lakes or playas.

In the southeastern angle of the Sevier Desert, there is a tract partially partitioned from the general plain by a series of coulées of basaltic lava extravasated during the Bonneville epoch. This contains several playas, marking localities where the drainage is checked but not completely imprisoned. The highest and most southerly of these differs from all the others in that its material is gypsum. It is probable that the deposit is independent of any special chemical reaction, and is due simply to discharge by evaporation of a mineral dissolved from the rocks. The streams whose waters occasionally flood the playa rise amongst strata of Jurassic and Triassic

[a] Howell, E. E., U. S. Geog. Surveys W. 100th Mer., vol. 3, p. 264.
[b] U. S. Geog. Surveys W. 100th Mer., atlas sheets 50 and 59.
[c] Howell, E. E., U. S. Geog. Surveys W. 100th Mer., vol. 3, p. 264.
[d] Gilbert, G. K., Lake Bonneville: Mon. U. S. Geol. Survey, vol. 1, 1890.

age, and such strata in the neighboring range are known to be highly gypsiferous. The heads of the streams were not examined. It was ascertained by digging in the playa that a portion of the deposit is amorphous and another portion crystalline. One phase of the precipitation results in the formation of small free crystals, which the wind sweeps from the surface of the playa and gathers into dunes. The dunes do not travel to a great distance, but are arrested by a low rhyolitic butte near by, to which they have given the name of White Mountain [a].

South Wash deposits.—The precise geologic occurrence and age of the country rock of the South Wash gypsum is uncertain. Geologists of the Wheeler survey mapped this region as Triassic, Jurassic, and Cretaceous, with overlying trachyte, rhyolite, and Quaternary deposits. Professor Talmage states that "the formation in the neighborhood of the deposit in question is mostly sandstone argillite with a top dressing of erratic bowlders of lava. * * * Ripple marks in great distinctness are frequent in the sandstone of this region, and other evidences of lake formation are common."[b] Detailed geologic field work will be required before these points can be settled.

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[a] Ibid., p. 223.

[b] Science, vol. 21, p. 85.

GYPSUM DEPOSITS IN OREGON.

By WALDEMAR LINDGREN.

CHARACTER AND EXTENT.

The only deposit of gypsum known to occur in Oregon is on the eastern border of the State, near the middle point of the boundary line, on a ridge dividing Burnt River and Snake River. It consists of beds of rock gypsum, which have a limited geographic extent. Smaller areas, which are continuations of these deposits, are reported to occur over the border, in Idaho. The material is of good quality and is well suited for economic uses. The gypsum is in part white and crystalline; in part, however, it contains thin strata and films of greenish chloritic mineral.

ECONOMIC DEVELOPMENT.

The gypsum beds have been known for thirty years, but have been developed only recently. In 1896 a mill was erected which was destroyed by fire the same year. The plant, however, has been rebuilt and is now in operation. It is situated on Burnt River, 4 miles below Huntington, at a station called Lime, on the Oregon Railroad and Navigation Company's railroad. From this place a winding road ascends a ridge to a point about 1,500 feet above the level of the river. The gypsum occurs about 200 feet below the summit of the ridge, on the slope facing Snake River. On account of the northwestward dip the development has been undertaken by means of tunnels. The elevation of the lower opening is approximately 3,900 feet above sea level. At this point a tunnel 170 feet long, connecting with an upraise 100 feet long, exposes gypsum rock of good quality 20 feet thick. The conditions for exploitation are excellent.

GEOLOGIC RELATIONS.

The lower portion of the ridge between Burnt River and Snake River is occupied by a series of old lavas, largely rhyolitic in character. Above these rests a sedimentary series, in which the gypsum is interstratified. The mineral occurs as elongated lenses, which are in places from 10 to 40 feet thick. The bed exploited rests on slates and limestones. It is covered by a thick series of shales, which contain a few intercalated strata of volcanic tuffs. Thick beds of limestones also occur in the series. The dip of the beds is low, to the northwest.

The period to which the gypsum beds belong is probably early Mesozoic. This is judged from the geologic relations of sedimentary beds of the region, but the evidence is not wholly clear.

GYPSUM DEPOSITS IN NEVADA.

By George D. Louderback.

CHARACTER AND EXTENT.

Gypsum has been found at a number of places in Nevada, but as systematic exploration of the State for it has never been made its exact distribution and extent can not be given.

The best-known deposits are in northwestern Nevada, at Lovelocks and Moundhouse, where gypsum has been developed commercially. These deposits occur in rocks of Mesozoic (probably Triassic) age. Beds of gypsum have also been reported from the Star Peak, Sonoma, and other ranges, and it is reasonable to believe that careful search would disclose many localities in northwestern Nevada.

The deposits which have been worked are generally of massive, compact, or granular rock gypsum, commonly white, more rarely yellowish in color. They are almost pure, and make a fine grade of plaster, as is shown by analyses and by the character of the manufactured product.

In the two localities studied in the field the gypsum is inclosed in white limestone, in series which, in addition, consist of quartzites and slates. With them are associated gypsiferous limestones and slates. In the slate the gypsum generally occurs in the form of selenite, sometimes in large crystals several inches across. Gypsum dirt, formed from the rock gypsum by secondary action, lying on the surface of the bed or on the lower hill slopes, or in gullies or other depressions, accompanies these deposits, and may prove to be of economic value.

Gypsum also occurs in the extreme southern part of the State, in an area on the border of the Grand Canyon province. Within that region some of the Mesozoic, especially Jurassic, sediments have long been known as gypsum bearing. These outcrop in the Spring Mountains and other ranges to the south. The deposits are mainly rock gypsum, having a rather compact structure, and are interstratified with shales and sands. Massive beds of rock salt occur in the same country, possibly in the same series.

Gypsum is found also in lenticular beds in the Carboniferous strata of the Spring Mountain Range, associated with limestone. The section, according to Gilbert, is:

Section of Carboniferous strata in the Spring Mountain range.

	Feet.
Bedded, fine-grained to saccharoidal limestone, gray and cream colored, separated by shaly layers so as to weather in steps, fossiliferous	500
Massive gypsum, white and red, in lenticular masses	0–70
Gray, massive, cherty limestone, fossiliferous	475

The eastern, central, and southwestern parts of the State make up the great Paleozoic (and Archean) bed-rock province. No deposits of sedimentary gypsum have, to my knowledge, ever been reported from this region. This mineral has not been particularly sought for, and future prospecting may bring it to light.

Lake beds of Tertiary or later age are widely distributed in Nevada. In some of these gypsum beds occur, associated with friable sands, clays and calcareous layers. Almost pure beds several feet thick are known. The gypsum occurs both as white granular layers and as selenite.

The gypsum may be formed by the action of sulphuric acid on lime-bearing rocks. In this process the sulphuric acid is derived from the oxidation of pyrite or other sulphides. Small bodies of gypsum having this origin are not uncommon, as might be expected from the abundant mineralization in the Nevada ranges, and the great depth of the zone of weathering in the Great Basin. Where the country rock is limestone, as is frequently the case throughout eastern and central Nevada (the Paleozoic province), the resulting gypsum is more or less granular, like ordinary rock gypsum, and in small exposures it is hard to determine its origin by its general appearance. But where the country rock is a lime-bearing volcanic rock, such as andesite, the resulting gypsum is in the form of selenite crystals, strewn, sometimes very abundantly, through the residual brown, yellow, red, or even white clayey earth. Such deposits are especially common in western Nevada, but are apt to be too irregular and uncertain for profitable working.

It may be noted that special attention has not until very recently been directed to the gypsum deposits of the State, since the local demand has been very small and the difficulty of solving the transportation problem has interfered with exportation to other States.

ECONOMIC DEVELOPMENT.

The gypsum deposits in southern Nevada have not been developed. They are many miles from any railway or large towns. They are, however, in the region that is to be traversed by the railroad, now building, which will connect Salt Lake and Los Angeles, and may become of economic importance within a few years.

The gypsum which has thus far been exploited is located in the northwestern part of the State. One of the deposits lies at the western base of the Humboldt Mountains, 4½ miles east from Lovelocks, a station on the Central Pacific Railroad. Considerable work was done there in 1891 to 1893, and elevated bins filled with gypsum are still standing. During the period of financial depression (1893) the work was abandoned. Recently a local company was organized to work the deposit. Many prospect holes have been sunk and a new cut has been

fractured, and recemented by banded, columnar aggregates of calcite. The greatest width of the exposure of gypsum is 130 yards, and, since faulting can not be determined and the dip is about vertical, this gives an estimate of the thickness of the bed.

The main deposit, which is cut off abruptly by diorite on the south side, runs north about 270 yards, with an average width of about a hundred yards, and then rapidly narrows to a thin band that soon gives out. The gypsum and its inclosing limestone are entirely surrounded by diorite, which is the chief country rock of the vicinity. The diorite is overlain at one point by a small area of andesite, which covers the limestone-diorite contact on the east side of the gypsum. A little farther northeast the diorite is covered by a small area of rhyolite. Limestone similar to the wall rock of the gypsum deposit outcrops at intervals in the diorite north of the main deposit, and is associated, at least at one point half a mile distant, with a comparatively thin bed of gypsum.

The gypsum is eroded more rapidly than the accompanying rock, and therefore a considerable depression had formed before quarrying was begun. Much of the material has been washed down an eastward-trending gully that drains the area and has formed, alone or with earthy detritus, gypsiferous alluvial deposits.

Thus far no layers of sandstone, limestone, or any other rocks have been found breaking the continuity of the main gypsum bed. The gypsum is rarely stained with iron, and, as before stated, its color is generally a nearly pure white. Several analyses show it to be of excellent quality, the chief impurity being $CaCO_3$. Some very subordinate bunches of pyrite were found in the upper west quarry.

The gypsum is apparently an original member of the stratigraphic series to which the limestones belong. On careful observation one may see the lamination of the bed. This consists not of structural variations, but in a very faint color banding, not noticeable in hand specimens, the alternating layers varying from gray to white. There appears to be no distortion or crumpling of the bed, although in places along the wall it is brecciated. Cracks extending from the surface into the gypsum, have allowed the percolating waters to carry down fine sand, which is found in the quarries in very thin, more or less vertical layers, or in horizontally extended bunches. Percolating waters have also in places hollowed out small caves, a foot or so across, which have smooth interior surfaces.

GEOLOGIC RELATIONS.

The Humboldt Mountains (the West Humboldt Range of the Fortieth Parallel Survey) form a range near the middle of northwestern Nevada, 80 or 90 miles east of the California-Nevada boundary line, and extend about 72 miles. They lie just southeast of the Humboldt

EXPOSURE OF GYPSUM AND LIMESTONE IN OPEN CUT AT LOVELOCKS, NEV., THE DEPOSIT SHOWING FOLDING AND CRUMPLING.

River and the line of the Central Pacific Railroad, which parallels them throughout their whole extent. These mountains are sharply separated into two groups by a transverse valley or pass, determined by faulting. The southern or Humboldt Lake group, in which the Lovelocks gypsum deposit lies, runs northeast and southwest for about 42 miles, with a maximum height of approximately 6,700 feet, or 2,700 feet above the Humboldt Valley. It is by far the lower of the two groups.

The rocks of this range may be divided into the bed rock and the superjacent series. The former consists of Triassic and Jurassic sediments—slates, limestones, and quartzites—somewhat metamorphosed, folded, and faulted. These are overlain unconformably by the superjacent series, which is made up of Cenozoic volcanics—rhyolites, tuffs, and basalts—which were affected by simple dislocation and tilting without folding at the time of the final upheaval of the range. This upheaval was in the nature of a tilting of the range as a mass, the west side being elevated along a fault line, the east side remaining comparatively depressed. Toward the north and more elevated end of the Humboldt Lake group the sedimentary series predominates; toward the south and more depressed end the volcanics, especially the rhyolites, are largely in excess.

The writer did not find any fossils in the vicinity of the gypsum; and their presence would not be expected, considering the conditions under which gypsum forms. The gypsum deposit, however, underlies a series of slates, which may be traced to Muttleberry Canyon, about two miles south, and these slates underlie shaly limestone beds, in which Prof. J. P. Smith, of Stanford University, has collected upper Triassic fossils. We may accordingly look upon the gypsum as being of Upper or Middle Triassic age. The Lower Triassic has not yet been recognized in the Humboldt Mountains.

The Virginia range, in which the Moundhouse deposit lies, runs north and south, approximately parallel to and from 8 to 16 miles east of the California-Nevada boundary line. Throughout the greater part of its extent—i. e., from its north end, opposite Pyramid Lake, for about 70 miles southward—it is a mass of Cenozoic volcanics. The elevation of the range in late Cenozoic time and the accompanying erosion were not sufficient to bring the older rocks—the bed-rock series—to the surface, even in the deep canyon of Truckee River, which cuts completely across the range in the vicinity of Reno. A short distance south of Virginia City, however, the older rocks may be seen, though still largely covered by lava flows and ash beds. This bed-rock series consists mainly of granitoid rocks, containing here and there larger or smaller disconnected included masses of the older strata, now considerably metamorphosed, and appearing as granular limestone, quartzite, or schist.

The age of the gypsum deposit may be inferred from general stratigraphic considerations. It belongs to the series of older rocks that were folded and intruded at the time of the post-Jurassic upheaval of the mountains, and lies unconformably below the Tertiary lavas. It is in a geologic province in which no pre-Triassic sedimentary rocks have been found. It is, therefore, probably Triassic or Jurassic, and the occurrence of other similar deposits in the same geologic province in the Triassic, notably the Lovelocks deposit above described, and the absence of such deposits from the known Jurassic of this region, make a strong case for the Triassic age of the Moundhouse beds. The nearest known fossiliferous strata are the limestones near Dayton, which is 6 miles, in an air line, east of the gypsum deposit. These yield marine forms of the Triassic period.

GYPSUM DEPOSITS IN CALIFORNIA.

By H. W. Fairbanks.

CHARACTER AND EXTENT.

The gypsum deposits of California are widely distributed over those portions of the State underlain by the younger geological formations. The mineral is found through nearly all portions of the Coast Ranges, particularly south of San Francisco Bay, in the foothills of the Great Valley, and in the valleys of southern California (see Pl. XXI). There are no instances known of its occurrence in commercial quantities in the older metamorphic rocks, as is the case with some of the deposits of Nevada.

Although so generally distributed over the State, beds of gypsum of sufficient size and purity to make them of value are comparatively rare. The deposits occur as interbedded strata, as veins, and in one instance as a layer or crust upon the surface of clay beds.

Nearly all the deposits are associated with clays which are gypsiferous. The interstratified deposits are of contemporaneous age, but the veins are later than the rocks with which they are associated, and are due to the concentration of the gypsum by percolating waters gathering it in solution from the clays or shales through which it was originally disseminated.

The interstratified beds, while of greater extent, are usually of poorer quality than the veins, and many deposits have been opened which contain such a percentage of impurities as to make them only locally available as fertilizer. In physical character this gypsum is softer than that in the veins, and is rarely crystalline.

The Tertiary clays all over California contain small amounts of gypsum. The gypsum is in the form of small nodules and sheets of clear cleavable selenite, which in many localities are scattered thickly over the surface. In the more consolidated clays and shales the gypsum forms little veins varying in thickness from that of a knife blade to an inch or more.

Some of the sinks of the Great Basin in southeastern California contain deposits of gypsum about which little is known. These are associated with salt beds and appear to have resulted from precipitation in lakes as the waters evaporated.

The purest gypsum is found in secondary deposits, and when they are of sufficient size and near lines of transportation they become of value in the manufacture of plaster of Paris. The gypsum in veins is usually white or light gray, and in some places becomes clear enough to be termed alabaster.

ECONOMIC DEVELOPMENT.

From an economic standpoint the development of the gypsum industry of California is in its infancy. Comparatively little gypsum is mined for manufacture into plaster of Paris, owing largely to cheap transportation from points outside of the State, although local manufacture of this product has intermittently assumed some importance.

The most of the extensive deposits are of a nature to be most valuable as land fertilizer. It has also been found by Professor Hilgard that gypsum has great value in neutralizing the alkalies present in large quantities in some of the valley lands of the State. In many cases the deposits are so situated as to be within easy reach of the lands which need them most. It is but natural that under such conditions the mining of gypsum as land plaster should become an important industry.

DESCRIPTIONS OF LOCALITIES.

Alamo Creek.—On Alamo Creek, 16 miles from Santa Maria, in San Luis Obispo County, there are a number of bunchy veins scattered over an area of 40 acres. Part of the material is white, and part grayish. The veins occur in a clay formation similar to that at Point Sal. Little work has been done there.

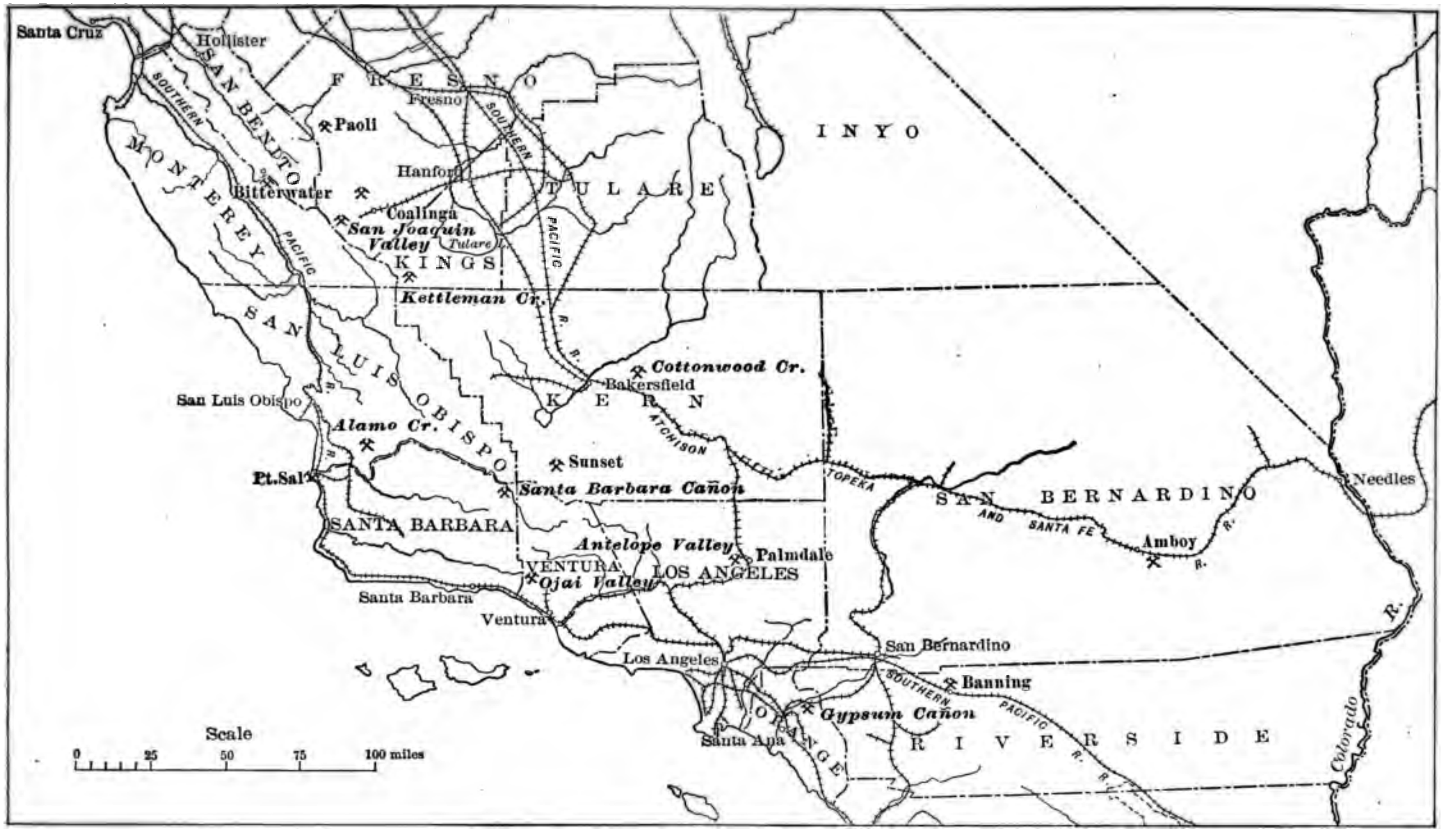
Amboy beds.—Extensive beds of gypsum occur in the Amboy sink, near the Santa Fe Railroad, in the eastern part of Mohave Desert. They are associated with beds of salt and were discovered while prospecting holes were being sunk in search of salt. Holes 10 feet deep encountered nothing but gypsum, which occurs in nodular or concretionary granules. The quality is apparently very good, although no analysis has been made. The deposit is overlain by a thin stratum of clay.

Antelope Valley.—A deposit lies on the borders of Antelope Valley in northern Los Angeles County, a little more than half a mile from Palmdale Station on the Southern Pacific Railroad.

The gypsum occurs as a stratum near the surface of a low hill and has a thickness of 25 feet. The area covered is about 25 acres. It is mined by surface workings. The quality is good, being about 95 per cent pure, and the deposit is thought to be almost inexhaustible. The gypsum is taken to Los Angeles and prepared for use as a fertilizer, wall plaster, and plaster of Paris.

Banning.—A deposit of gypsum has been opened at Banning, near the Southern Pacific, in Riverside County. The material is shipped to Colton, near San Bernardino, and is used in the manufacture of plaster of Paris.

Bitterwater deposit.—This deposit is situated on the southwest side of Bitterwater Valley, in San Benito County, 10 miles east of Kings



MAP OF SOUTHERN CALIFORNIA SHOWING GYPSUM LOCALITIES.

City, at an elevation of 1,900 feet. It outcrops along the top of a series of ridges, dipping gently westward. It is overlain by clayey soils and covers an area of several hundred acres. The upper portion of the deposit is composed of massive gray gypsum, and, according to analysis, is 90 per cent pure. The thickness of the deposit is from 3 to 7 feet. This stratum is underlain by another, less pure, containing only 40 to 60 per cent, the impurities being lime, clay, and sand. The gypsum is soft and marly, and can be advantageously used for fertilizing purposes.

Coalinga mine.—This mine is situated 9 miles north of Coalinga, on the foothills of the Coast Ranges, in Fresno County. The workings consist of open cuts. At one the gypsum was found in a stratum 10 feet in thickness. The hillside has been penetrated 60 feet. At another cut, 100 yards south and a little below, are two beds. They are interbedded with clay and sandy calcareous shales. The strata dip 20° to the southeast. The gypsum is hauled from the mine to Coalinga, and there ground in a mill erected for the purpose. The material is used as a fertilizer in Tulare and Kings counties.

Cottonwood Creek.—Gypsum deposits of varying quality occur for many miles along the lower foothills of the Sierra Nevada, reaching from Caliente on the south nearly to Porterville on the north.

In the valley of Cottonwood Creek, 5 miles north of Pampa station, on the Southern Pacific Railroad, the beds are rather extensive, and a number of mines have been opened. The gypsum here seems to occur both as a crust upon the surface and as interstratified beds. The latter vary in thickness from 20 inches to 5 feet, and lie upon a bed of marl. This gypsum is not so pure as that upon the surface. The surface deposit conforms to the slope of the ground, and seems to have been formed through concentration as erosion removed the soft clayey and marly strata. The material is sacked and hauled 8 miles to Wade station, and is used for fertilizing purposes.

Gypsum Canyon.—A deposit lies in a small canyon, known as Gypsum Canyon, on the western slope of the Santa Ana Range, in Orange County. It is in the form of a bunchy vein in rocks of probable Upper Cretaceous age. The strata are chiefly sandstone. The deposit has a thickness of 8 to 10 feet. The gypsum is white and crystalline and almost as clear as alabaster. At one spot a mass of dolomite was found inclosed in it.

Kettleman Valley.—This is situated in southwestern Kings County, at an elevation of 425 feet. The deposit has been worked intermittently and the material obtained used as a fertilizer. Some selected samples showed 94 per cent gypsum, but the rock mined is generally poorer. It has been developed by open cuts.

Paoli mine.—This mine is situated on the eastern edge of the coast ranges 5 miles south of Big Panoche and 18 miles southwest of Men-

dota station, in Fresno County. The main ridge on which the deposit occurs extends for 300 feet along the north side of Tome Creek. From this ridge four spur ridges extend down in a northerly direction. The deposits occur on all of these ridges, dipping slightly toward the valley on the east. The deposit on the main ridge, where most of the work has been done, shows a thickness of 30 feet, but the bottom has not been exposed. At the foot of the east slope of the third spur there is exposed in a canyon a bed 18 feet thick. Everything indicates that these deposits are very large.

Analyses made in the laboratory of the Agricultural Department at Berkeley gave the following results:

Analysis of gypsum from Paoli mine, California.

	Gypsum	Clay.	Moisture and lime.
No. 1. Summit of main ridge	95.24	1.98	2.78
No. 1. Second spur	94.74	1.52	3.74
No. 3. Third spur	92.90	2.60	4.50
No. 4. Fourth spur	82.20	8.21	9.59

The average of the whole deposit is probably about 90 per cent. This excels in purity most of the gypsum found in California, and portions may be good enough for plaster of Paris.

Point Sal.—The deposits at Point Sal have been considered among the most important, both as to quality of gypsum and as to extent of the deposits. Although they are among the earliest worked in the State, they have been lying idle for some years. They have the form of bunchy veins in soft Tertiary clays, and have been worked by means of tunnels. The gypsum is conveniently situated for shipment, as it is only necessary to haul it 2 miles to a chute erected upon the cliffs. From this it is lowered by cable to ships moored just outside the rocks. The material is white and very pure, approaching alabaster in appearance. The veins are not well exposed. They are said to be two in number and to dip at varying angles. The gypsum can be mined and placed on shipboard for about $2 a ton.

Ojai Valley.—There is an undeveloped bed of gypsum on the hill below the grade that leads to the upper Ojai Valley in Ventura County. It is exposed for a width of 15 to 20 feet in a canyon on the south side of the road and dips slightly to the east. Another outcrop, perhaps the same bed, appears a mile distant, on the opposite side of the hill. The locality is so situated that it can be reached by the construction of a short road.

San Joaquin Valley mine.—This mine is situated 4 miles northwest of Coalinga, in Fresno County, and at an elevation of 1,000 feet. The

gypsum occurs in bunchy deposits in a recent formation and varies much in character. It has been mined for use as a fertilizer.

Santa Barbara Canyon.—The gypsum veins are on the east side of Santa Barbara Canyon, in Santa Barbara County. The material is of good quality, some of it being as clear as alabaster and capable of taking a good polish. The outcrop is much broken and the development does not show whether gypsum is present in sufficient quantity to pay for working. The veins are inclosed in Tertiary clays, which are extensively developed in this region and everywhere carry more or less gypsum.

Sunset district.—This district is situated on the eastern slope of the coast ranges southwest of Bakersfield. The region is particularly noted for its oil wells. The gypsum occurs as a soft, chalk-like rock interstratified with other beds. It sometimes reaches a thickness of several feet. The formation is similar to that on Cottonwood Creek. Analyses of specimens in the laboratory of the State mining bureau gave 86.07 gypsum for one and 60 to 70 per cent for others.

GEOLOGIC RELATIONS.

The gypsum deposits of California appear generally to be confined to formations of Neocene age. There are some exceptions to this rule, notably in the case of the Gypsum Canyon deposit, in rocks of Cretaceous age, and those in the Amboy sink, probably of Pleistocene origin.

The Neocene in California is characterized in many localities by extensive beds of clay and clay shales which are gypsum bearing. The clays of the Monterey formation, which belong to the Lower Neocene, are particularly prominent through the central portion of the coast ranges. Another horizon of later Neocene age is particularly extensive about the borders of the southern portion of the Great Valley. This formation contains the interstratified gypsum beds, which are generally of poorer quality than the veins and are more particularly adapted to use as a fertilizer. The argillaceous beds in the recent geological formations are generally impregnated with gypsum and alkalies, a fact leading to the supposition that they may have been formed in basins more or less separated from the open ocean.

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PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

[Bulletin No. 223.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

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